JUNE 2014

NATIONAL GEOGRAPHIC

1ST RANGER BN
MILITARY WORKING DOG
GUARDIANS OF THE NIGHT

HERO DOGS

A SOLDIER'S BEST FRIEND

Layka saved lives of U.S. troops in Afghanistan after she was shot and gravely wounded.

TREASURES OF A LONG-LOST PERU TOMB 54

RETURN OF THE PUFFINS 78

HOW TO FARM A BETTER FISH 92

SIBERIA'S MEDICAL TRAIN: CARE FOR THE FORGOTTEN 114

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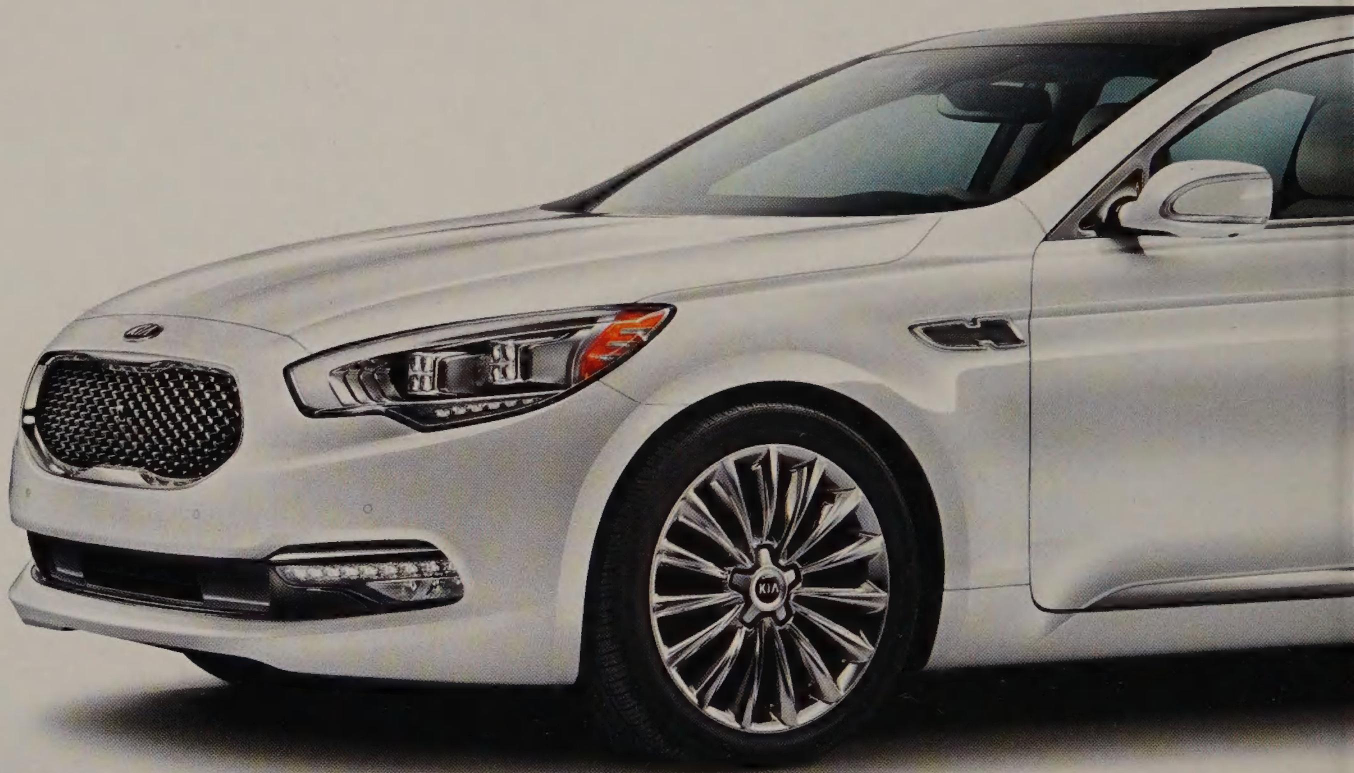

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VOL. 225 ▪ NO. 6

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DANNY GREEN

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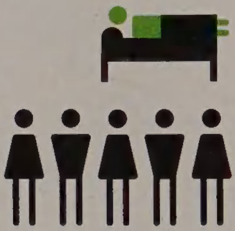

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DIGITAL EDITIONS

National Geographic is available on the iPad, the Kindle Fire, and the iPhone.

War Dogs
Video
See canine companions from Vietnam to Afghanistan.

Peru Tombs
Interactive
Watch a 3-D video showing reconstruction of the tomb.

PHOTO: NGM VIDEO. ART: FERNANDO G. BAPTISTA, NGM STAFF

On the Cover Layka, a Belgian Malinois, won a medal for heroism after saving the lives of her handler and members of his U.S. special operations unit in Afghanistan.
Photograph by Martin Schoeller

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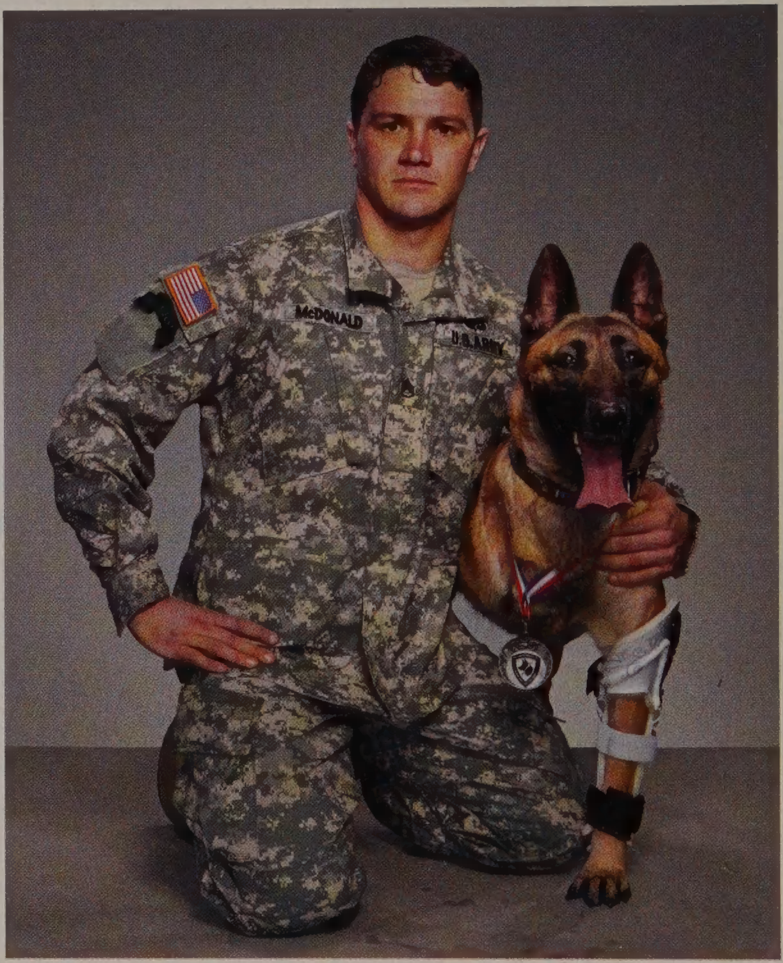
EDITOR'S NOTE

Man's Blessed Friend

Layka, the dog pictured on our cover and here, was two when she was sent to help clear an enemy compound in Afghanistan. During her search she was shot by enemy forces and took four rounds from an AK-47 at point-blank range. Despite her injuries, she attacked and subdued the shooter, protecting her handler, Staff Sgt. Julian McDonald, and other members of the team. It took seven hours of surgery, including the amputation of a limb, to save her. In 2012 Layka was presented with a medal of heroism and adopted by McDonald, who now trains dogs and their handlers at Fort Benning, Georgia.

Dogs have been our best friends for at least 14,000 years.



Layka, a Belgian Malinois, was adopted by Staff Sgt. Julian McDonald after she saved his life.

Our cover story, "The Dogs of War," is about a special bond. Dogs have been our best friends for at least 14,000 years. The relationship is in our genes and theirs. When it comes to the dogs of war, the stakes couldn't be higher. The penalty for a misstep by either partner can be injury or death. The U.S. military deploys more than 500 dogs worldwide at any given time. Each year a few are killed in action.

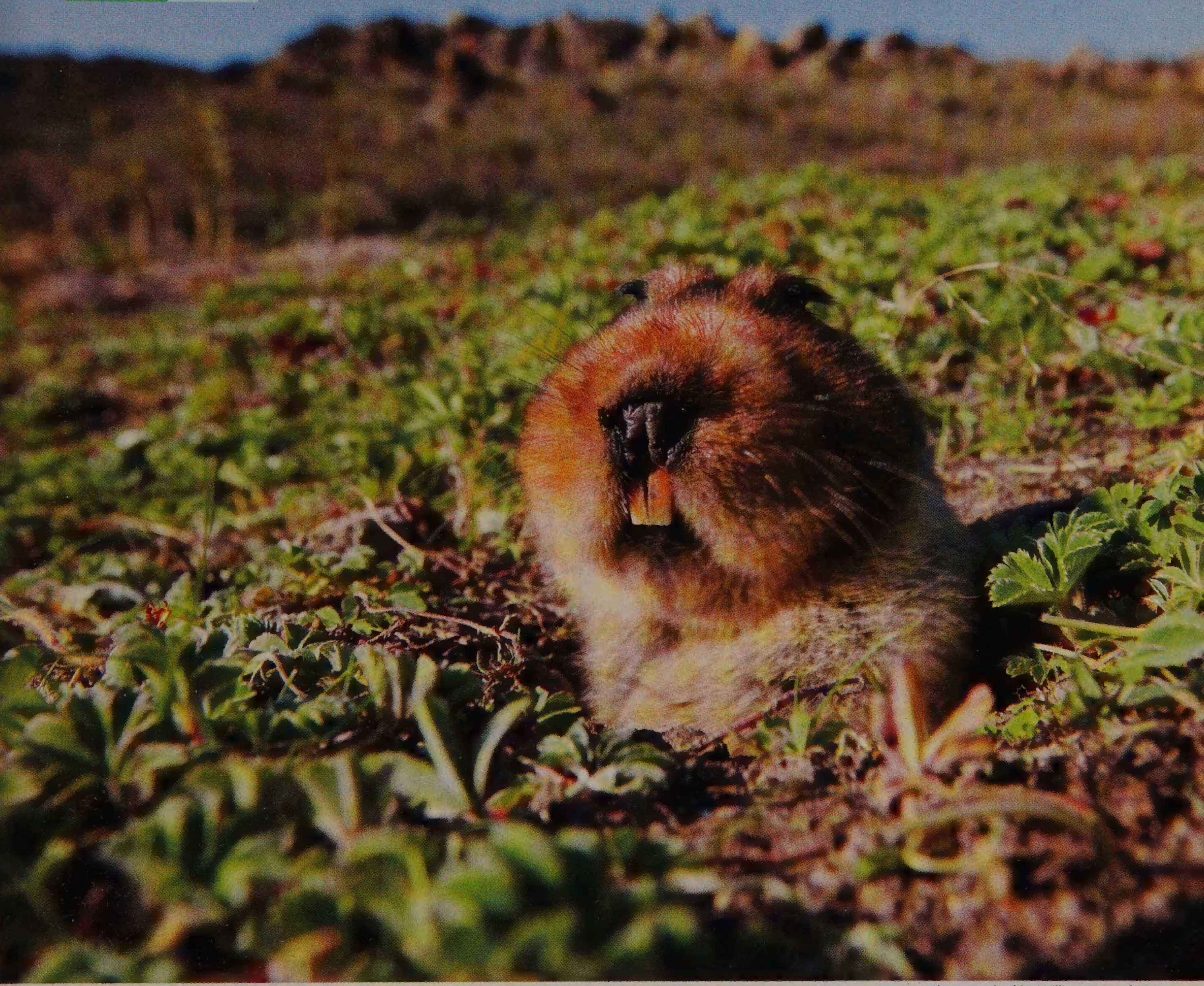
When Layka bounded out of the van that delivered her to Sergeant McDonald's home—a special brace allows her to run as if she'd never lost a leg—she instantly recognized him, even though they'd been together only a month before she was shot. "Her excitement brought me to tears," McDonald says. "She was the sole reason why I was living and breathing and able to come home to my son and wife."

Chris Johns

PHOTO: MARTIN SCHOELLER

ETHIOPIA
Indian Ocean

Giant Mole Rat *(Tachyoryctes macrocephalus)*
Size: Body length, 22 - 31 cm (8.6 - 12.2 inches) **Weight:** Up to 1.2 kg (42.3 oz)
Habitat: Afroalpine wetlands, grasslands and moorlands in the Bale Mountains National Park of southern Ethiopia **Surviving number:** Abundant locally; range small and declining



Photographed by William Burrard-Lucas

WILDLIFE AS CANON SEES IT

Mighty bite. The giant mole rat is equipped with formidable incisors, which it displays as a warning when faced by rivals or predators. Its large teeth are also its primary tool when digging burrow systems, complete with a tunnel to a "hay pile" for rubbish and several foraging tunnels. Reluctant to stray far, the mole rat spends just an hour or so a day gathering grass and herbs with half its stocky body still in the tunnel. But trouble comes home to it with predation by the rare Ethiopian wolf and raptors, plus overgrazing of its habitat by domestic livestock.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.

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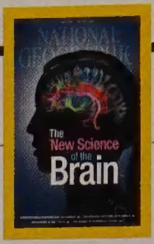

The New Science of the Brain

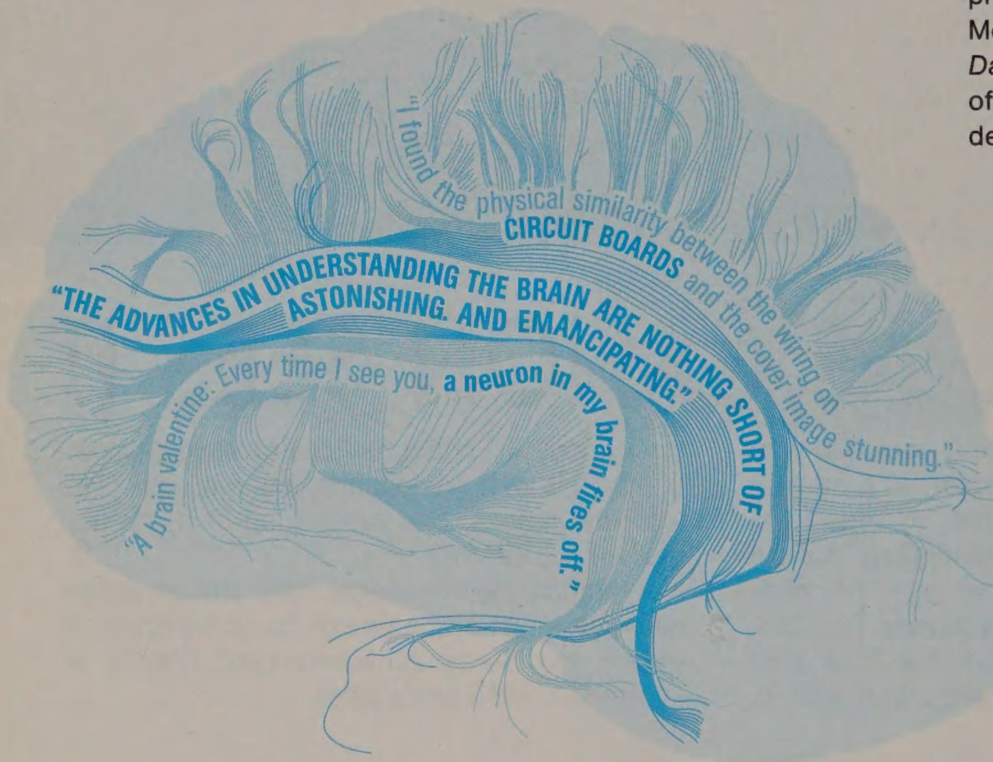
February 2014

There's No Place Like Home

It seems Garrison Keillor and I grew up in the same town—except mine was in Michigan. Each of us constructs a sort of geographical-highlight map of places we've lived. Even years later my recollections can help a traveler find the best restaurants or avoid shadier parts of town. I recall reading that chimps likely use a mental picture of their forest to find what they need to survive. The capacity to create a mental sketch of the most relevant parts of the environment must be a key survival technique that humans inherited from the earliest primates. Of course we no longer need to know where to find the best fig tree, just the nearest coffee shop. What to call such an important survival construct? May I suggest we call it a "Keillor Projection"?

CHARLES A. GIGLIO
Frederick, Maryland

FEEDBACK *Readers responded to the "Secrets of the Brain" story.*


"I found the physical similarity between the wiring on CIRCUIT BOARDS and the cover image stunning."
"THE ADVANCES IN UNDERSTANDING THE BRAIN ARE NOTHING SHORT OF ASTONISHING. AND EMANCIPATING."
"A brain valentine: Every time I see you, a neuron in my brain fires off."

I'm a New York City native but found myself in Minneapolis—in flyover country—for 11 years. The first winter welcomed my wife and me with temperatures that, for two weeks, never rose to 0°F. But we warmed to the place and adopted our two girls there. We returned to the New York area in 2004 yet still feel drawn to the Twin Cities and all their many memories.

JOHN F. HEENEHAN
Madison, New Jersey

Garrison Keillor is a charming and talented man. However, his ubiquity these days reminds me of a Jimmy Buffett of the northern latitudes.

MURRAY BOLESTA
Green Valley, Arizona

Erika Larsen's "slow photography" reminds me of Joel Meyerowitz's book *A Summer's Day*, capturing the essence of a place and time from a deeply personal perspective.

JOHN HOLLEY
Fairfax, Virginia

Secrets of the Brain

On page 43 of "Secrets of the Brain," dopamine is said to be a protein. Although dopamine is derived from tyrosine, an amino acid that is a common subunit of proteins, dopamine is a catecholamine, not a protein.

CHRIS GLANTZ
Pittsford, New York

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5. [illegible]
6. [illegible]
7. [illegible]
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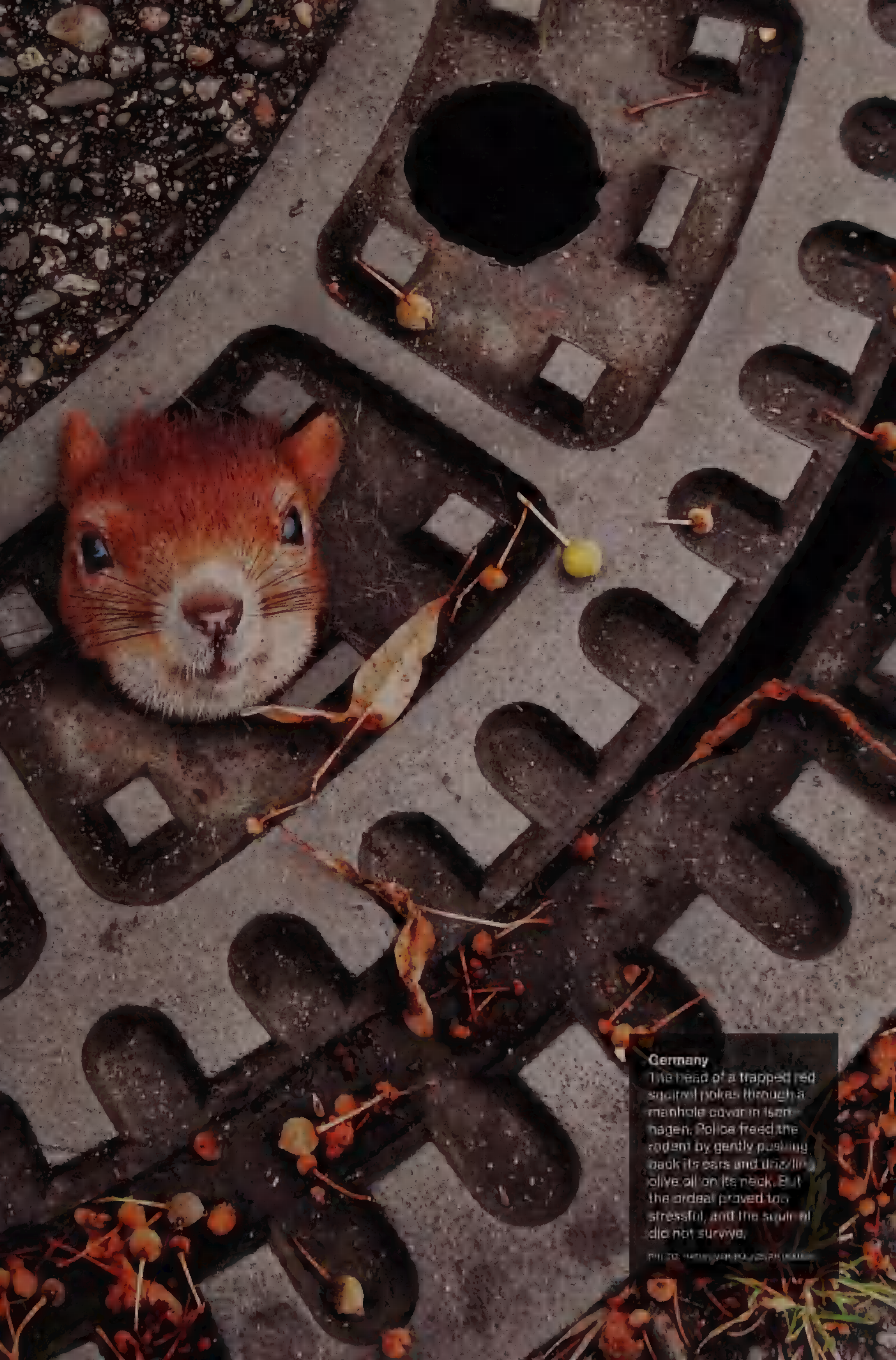

Germany
The head of a trapped red squirrel pokes through a manhole cover in Isenhagen. Police freed the rodent by gently pushing back its ears and drizzling olive oil on its neck. But the ordeal proved too stressful, and the squirrel did not survive.

[illegible]

England
To celebrate the 60th anniversary of Queen Elizabeth II's coronation, Princess Anne's dress holds court in Buckingham Palace. Nearly three years old at the time of her mother's ceremony, Anne was deemed too young to attend.

[illegible]

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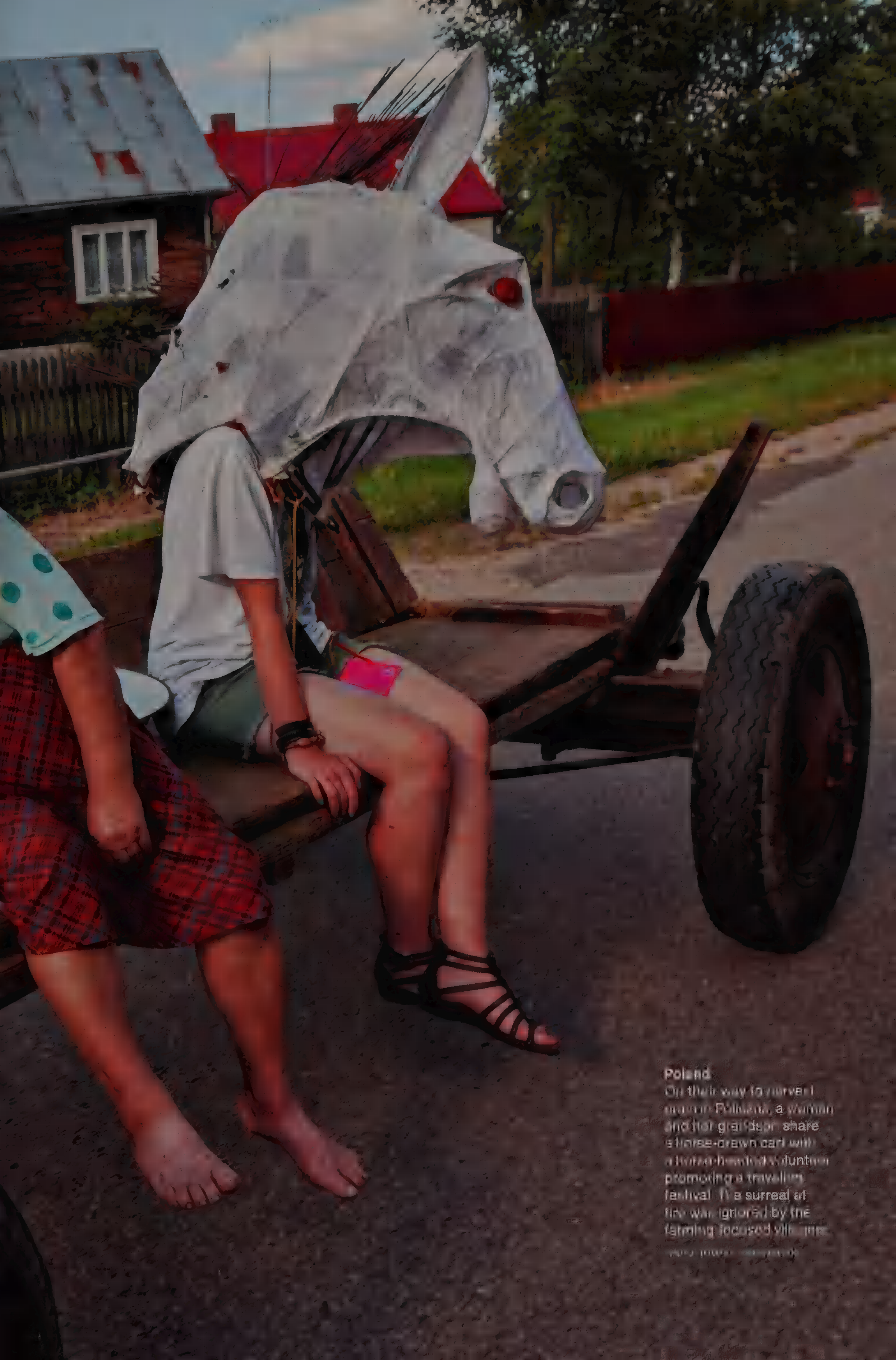

Poland
On their way to harvest grain in [illegible], a woman and her grandson share a horse-drawn cart with a horse-headed volunteer promoting a travelling festival. The surreal affair was ignored by the farming-focused villagers.

[illegible]

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Meet the amazing scientists, storytellers, and innovators of National Geographic's 2014 Emerging Explorers Program. These are tomorrow's visionaries, making discoveries, making a difference, and inspiring people to care about the planet.

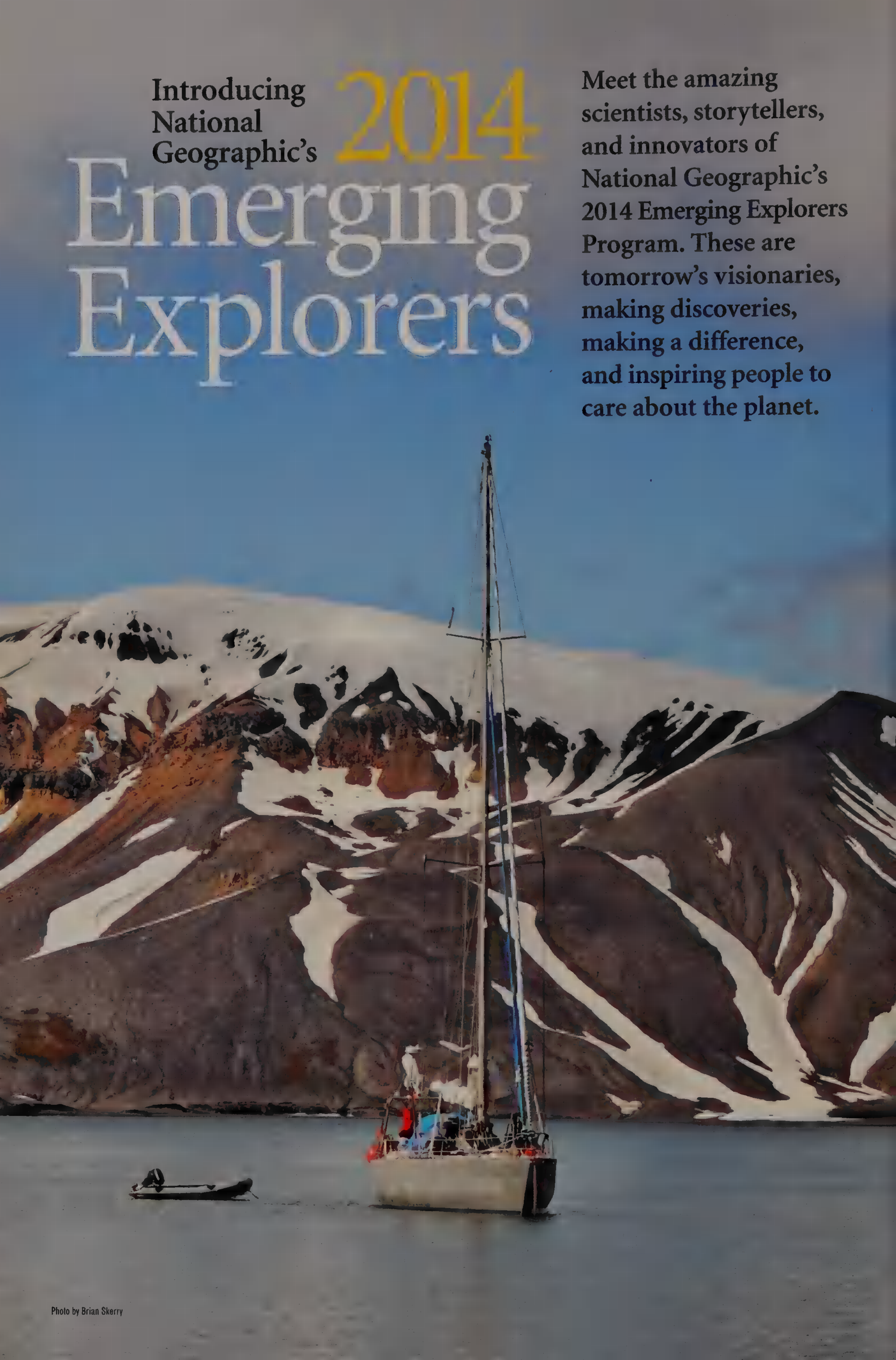


Photo by Brian Skerry

Inventor
Jack Andraka developed a new, potentially lifesaving test to detect pancreatic, lung, and ovarian cancer with greater accuracy at early treatable stages.

Photo by TEDxYouth@SanDiego, Noah Larky

Educator
Shabana Basij-Rasikh empowers a new generation of young women to rebuild Afghanistan, expanding their access to education worldwide and at the innovative girls' school she founded in Kabul.

Photo by David LeRoy Hunsaker

Conservation Biologist
Shivani Bhalla safeguards the future of Kenya's rapidly disappearing lions, using research and community outreach to reduce conflict between people and lions who share landscapes.

Photo courtesy of Ewaso Lions

Ecologist & Epidemiologist
Christopher Golden studies the connection between global environmental changes and human health, using empirical data to predict problems, guide solutions, and shape actionable policies.

Photo by Jon Betz/NGS

Marine Biologist
David Gruber discovers new biofluorescent marine creatures that he engineers to enable medical breakthroughs, and designs cameras and vehicles to revolutionize deep ocean exploration.

Photo by Dan Tchernov

Paleontologist
Nizar Ibrahim combs the Sahara for clues of life in the Cretaceous period, unearthing huge dinosaur bones and discovering a new species of flying reptile that soared 95 million years ago.

Photo by Robert Loveridge

Creative Conservationist
Asher Jay uses groundbreaking design, multimedia arts, and literature to inspire global action to combat illegal wildlife trafficking, advance environmental issues, and promote humanitarian causes.

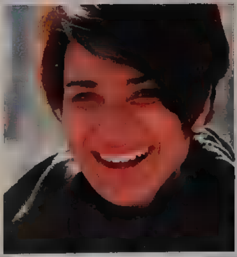


Photo by Eric Steinhouser

Photo courtesy of Juliana Machado Ferreira

Conservation Biologist
Juliana Machado Ferreira fights Brazil's illegal wild pet trade, using fieldwork, genetic research, and educational outreach to empower police, strengthen laws, change habits, and protect species.

Photo by © Roberto Masotti

Artist, Writer, & Musician
Paul D. Miller/DJ Spooky creates multimedia performances and installations blending artistic genres, academic disciplines, and data to engage audiences in environmental and social issues.

Photo by Rolex Awards/François Schaer

Environmentalist
Maritza Morales Casanova builds a new generation of environmentally aware leaders, volunteers, and social entrepreneurs through her unique educational park for children in Mexico.

Photo by Jerry Aronson

Social Entrepreneur
Sanga Moses tackles Uganda's energy, food, health, and deforestation crises through novel technology that converts waste into clean cooking fuel.

Photo by Silvio Palladino/Unveil Arts

Author & Campaigner
Tristram Stuart wages global war against food waste, transforming efforts to fight hunger, reverse devastating environmental impact, and make the issue into an international priority.

Photo by Eliza Grinnell/Harvard SEAS

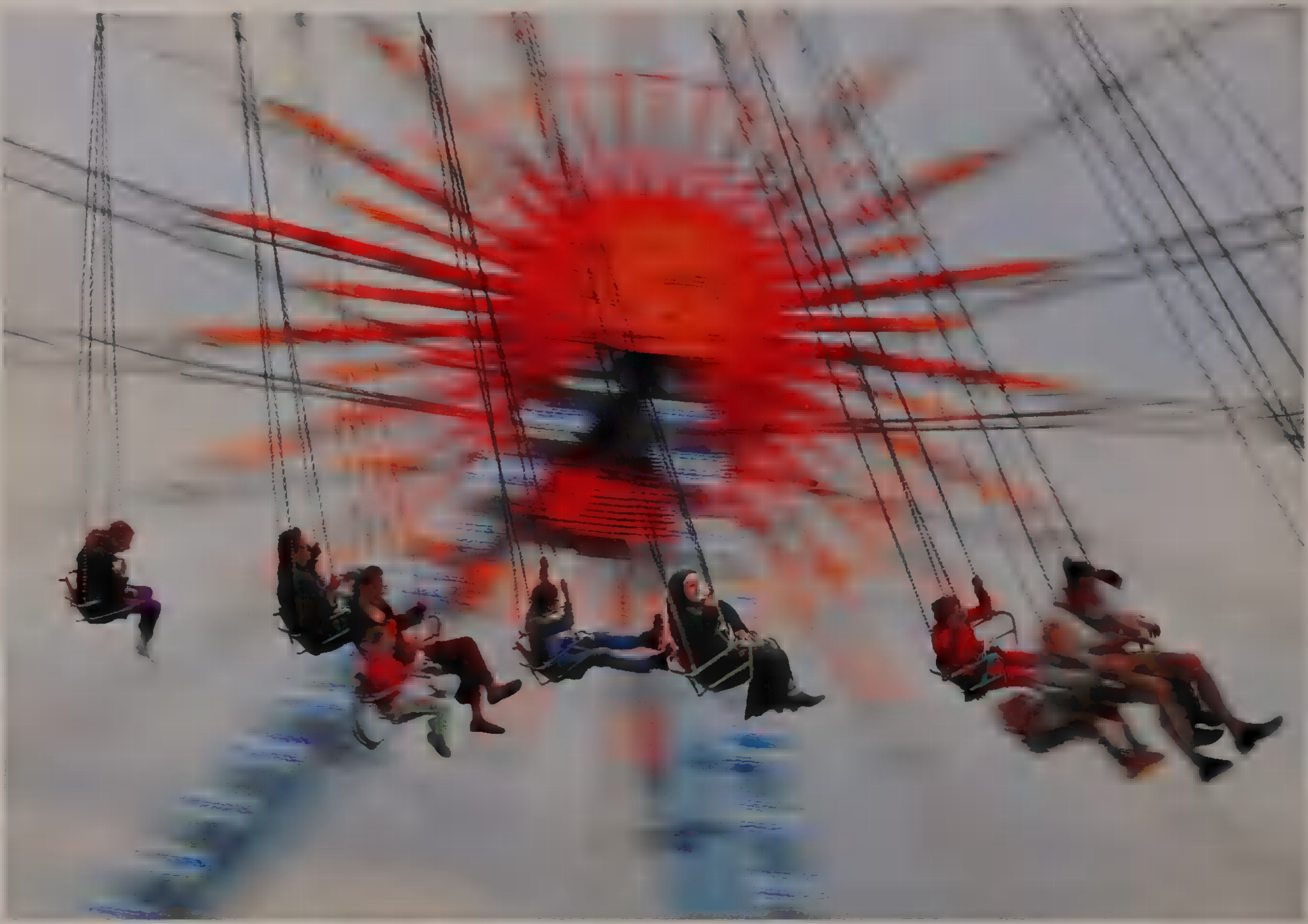
Electrical Engineer
Robert Wood develops robots that are ultra-small, flight-worthy, soft, and uniquely equipped to gather data, advance medicine, assist agriculture, aid search and rescue missions, and more.

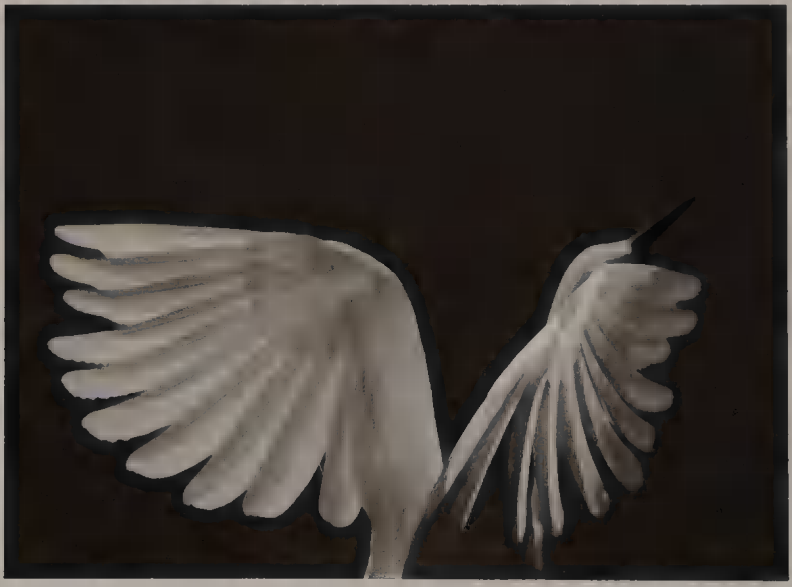
Photo by John Todd

Nanoscientist
Xiaolin Zheng invented a way to create thin, flexible solar cells with the potential to transform the practical, affordable, widespread application of solar power.

Visit nationalgeographic.com/emerging to see and hear the Emerging Explorers.

Assignment: Imagine If For June's assignment, we requested scenes that made you dream. For future assignments, visit *yourshot.nationalgeographic.com/assignments-stories*.





Veronika Kolev Toronto, Canada

At the Oktoberfest in Munich, Germany, Kolev pointed her camera at a nun riding a swing carousel. After the nun (at center) got off the ride, Kolev congratulated her on her bravery. The woman responded that it had been her greatest dream to ride the swings.

Nicholas Paoni Encinitas, California

On a small bridge over California's San Elijo Lagoon, Paoni photographed an egret hunting in the shallow water. When it disappeared under the bridge, Paoni moved his camera to capture the bird emerging from the other side.

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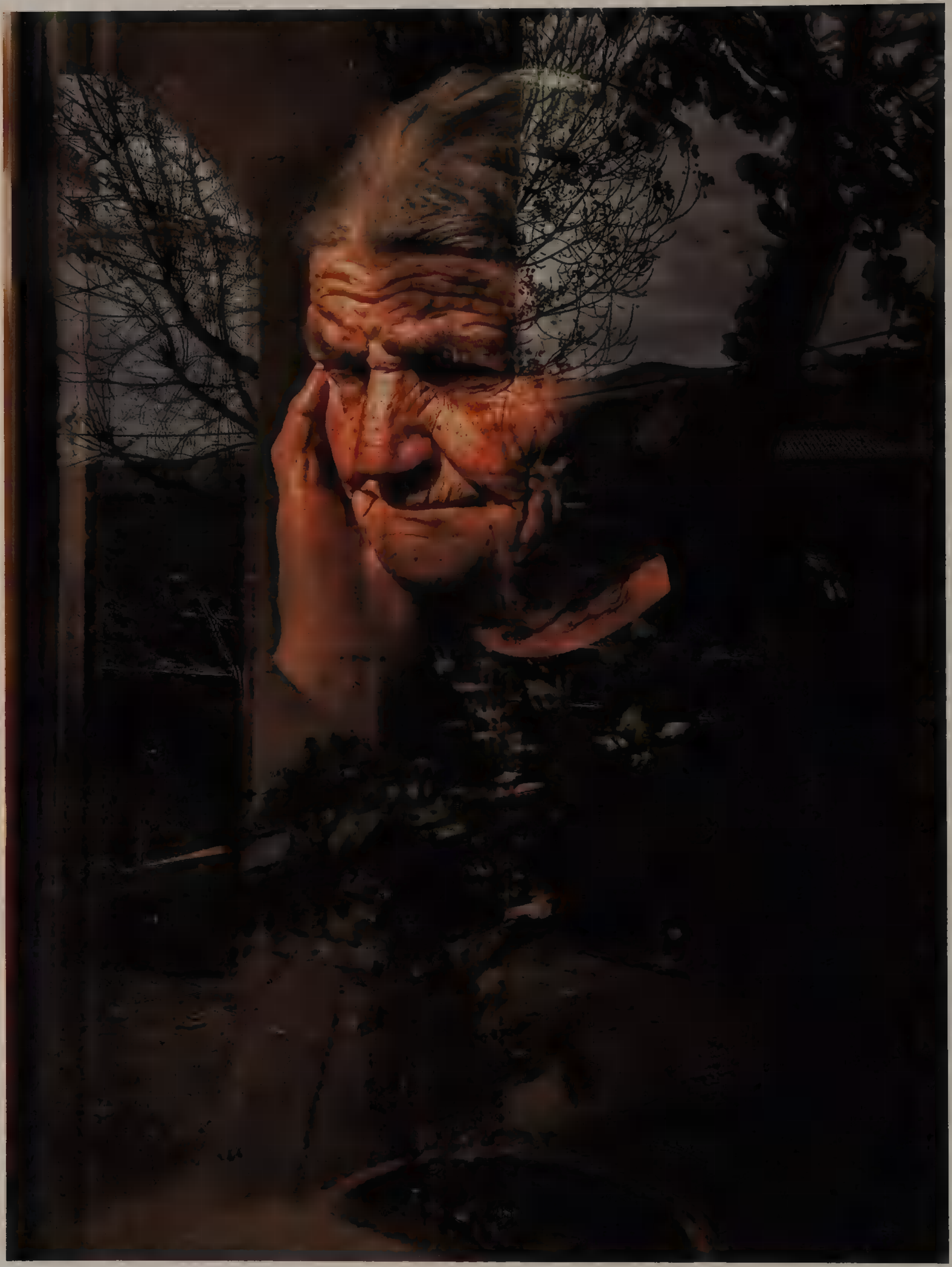

Tarek Touma Beirut, Lebanon

During a lunch break Touma, a doctor of osteopathy, left his clinic in northern Lebanon to get something from his car. Outside the building he noticed that his next patient, an elderly woman, was staring intently while she waited for her appointment, and he snapped this photo with his smartphone.

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NEXT

Feeling Red

Most redheads experience pain differently than the rest of us. Their hair color is caused by a mutation in the skin's melanocortin-1 receptor gene, which may "inadvertently activate" similar receptors in the brain that process anxiety and pain, says Anthony G. Doufas of the Outcomes Research Consortium of clinical anesthesiologists.

Anecdotal evidence long held that redheads were harder to anesthetize. The consortium tested this theory and found that redheads required 19 percent more gas for general anesthesia. They're also more sensitive to thermal pain and more resistant to local anesthesia. No wonder the *Journal of the American Dental Association* reports redheads are "more than twice as likely" to avoid the dentist's chair. —*Eve Conant*

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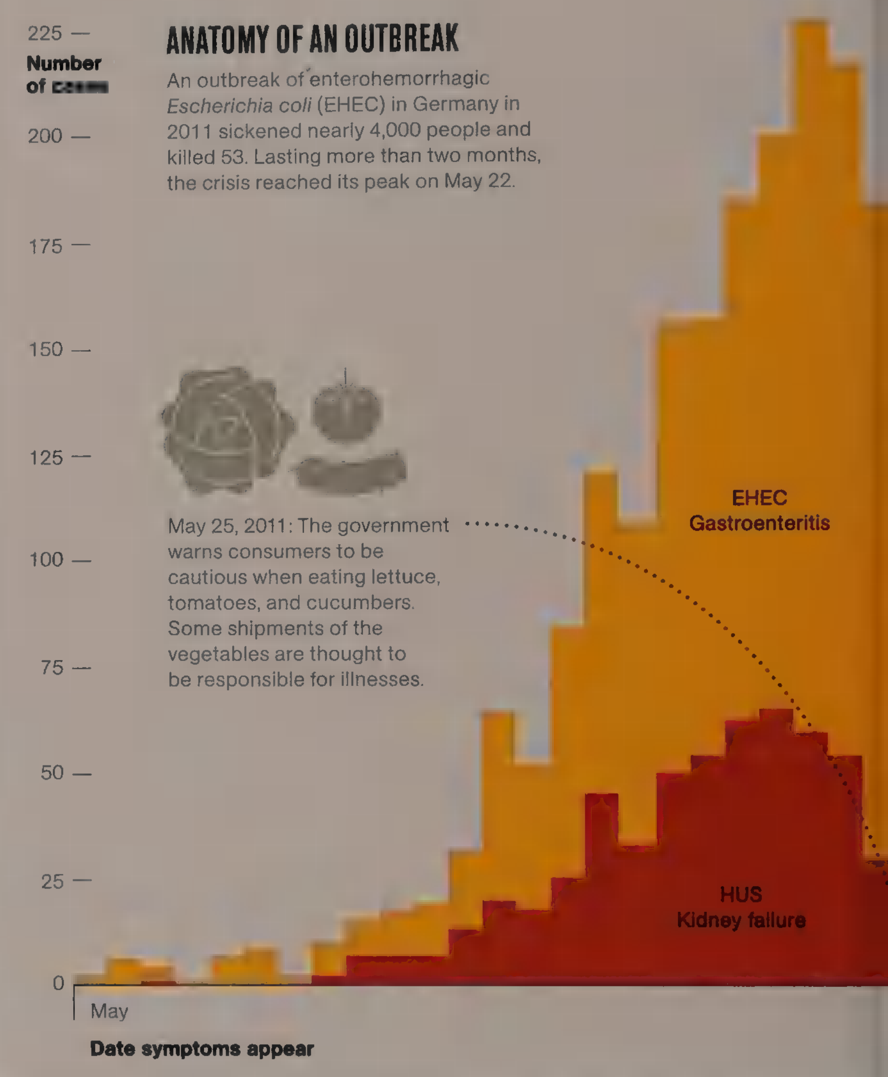
Foodborne Diseases

How often does food make us sick? Since most cases of food poisoning go unreported, the true extent of global foodborne illness is unknown. Improvements in international monitoring have led to greater public awareness, yet the rapid globalization of food production increases consumers' vulnerability by making food harder to regulate and trace. "We have the world on our plates," says Hilde Kruse of the World Health Organization. "But with more options comes more risk." *—Kelsey Nowakowski*

GERMANY'S E. COLI CRISIS



ANATOMY OF AN OUTBREAK

An outbreak of enterohemorrhagic *Escherichia coli* (EHEC) in Germany in 2011 sickened nearly 4,000 people and killed 53. Lasting more than two months, the crisis reached its peak on May 22.

May 25, 2011: The government warns consumers to be cautious when eating lettuce, tomatoes, and cucumbers. Some shipments of the vegetables are thought to be responsible for illnesses.

UNKNOWN PATHOGENS

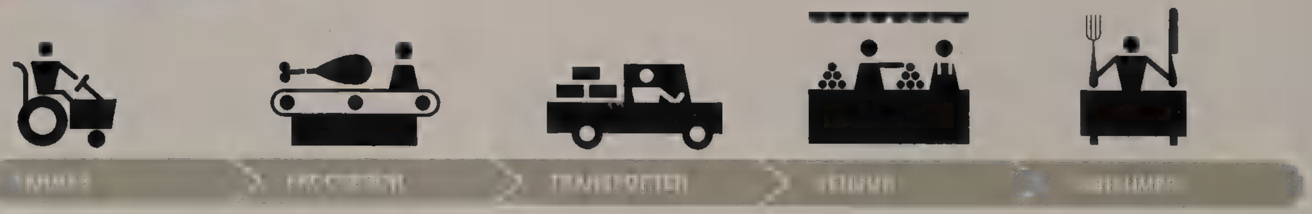
80%

PORTION OF FOODBORNE ILLNESSES CAUSED BY UNKNOWN AGENTS IN THE U.S., 2011

The remaining 20 percent are caused by 31 known pathogens.

RISKS IN THE FOOD CHAIN

Food contamination can occur at any stage from farm to table.



FARMER	PROCESSOR	TRANSPORTER	RETAILER	CONSUMER
Contaminated water, seed, equipment, workers, and animals can taint food.	Poor process controls can create unhygienic conditions that allow pathogens to grow.	If not stored at proper temperatures, food in transit may spoil and be unsafe to eat.	Warm temperatures and poor sanitation in stores can allow bacteria to multiply.	Unclean kitchens and insufficient cooking can further raise the risk of getting sick.

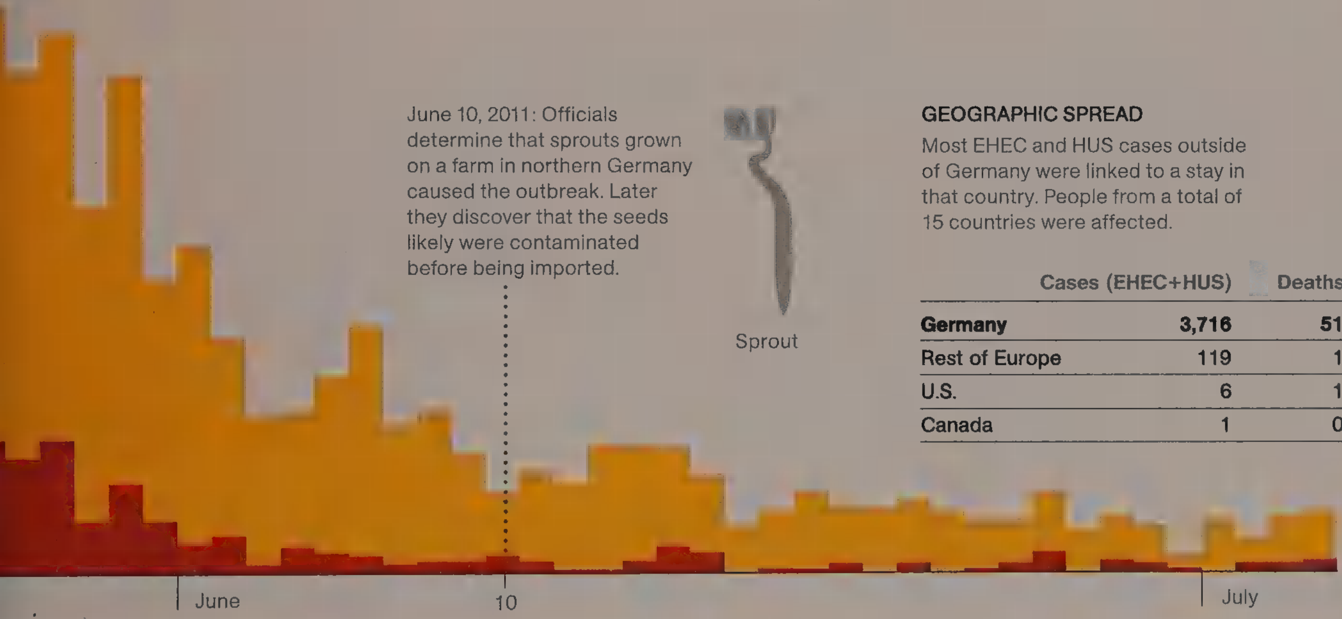
HOW IT AFFECTS PEOPLE

EHEC is generally self-resolving, but it can lead to hemolytic uremic syndrome (HUS), which can be fatal.

Incubation period: 6-10 days

- 🟧 EHEC symptoms: abdominal cramps, bloody diarrhea, fever, vomiting
- 🟥 HUS symptoms: red blood cell destruction, acute kidney failure

4%
Fatality rate



June 10, 2011: Officials determine that sprouts grown on a farm in northern Germany caused the outbreak. Later they discover that the seeds likely were contaminated before being imported.

GEOGRAPHIC SPREAD

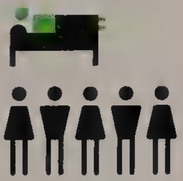
Most EHEC and HUS cases outside of Germany were linked to a stay in that country. People from a total of 15 countries were affected.

	Cases (EHEC+HUS)	Deaths
Germany	**3,716**	**51**
Rest of Europe	119	1
U.S.	6	1
Canada	1	0

THE IMPACT

EVERY YEAR ONE IN SIX AMERICANS GETS SICK FROM FOOD POISONING.

Most people will recover without any lasting effects.



ESTIMATED NUMBER OF PEOPLE AFFECTED BY ALL FOODBORNE ILLNESSES IN THE U.S. EACH YEAR

48,000,000	128,000	3,000
Sickened	Hospitalized	Killed

[illegible]

2.3%

GRAPHICS: ÁLVARO VALIÑO. SOURCES: CENTERS FOR DISEASE CONTROL; WORLD HEALTH ORGANIZATION; ROBERT KOCH INSTITUTE

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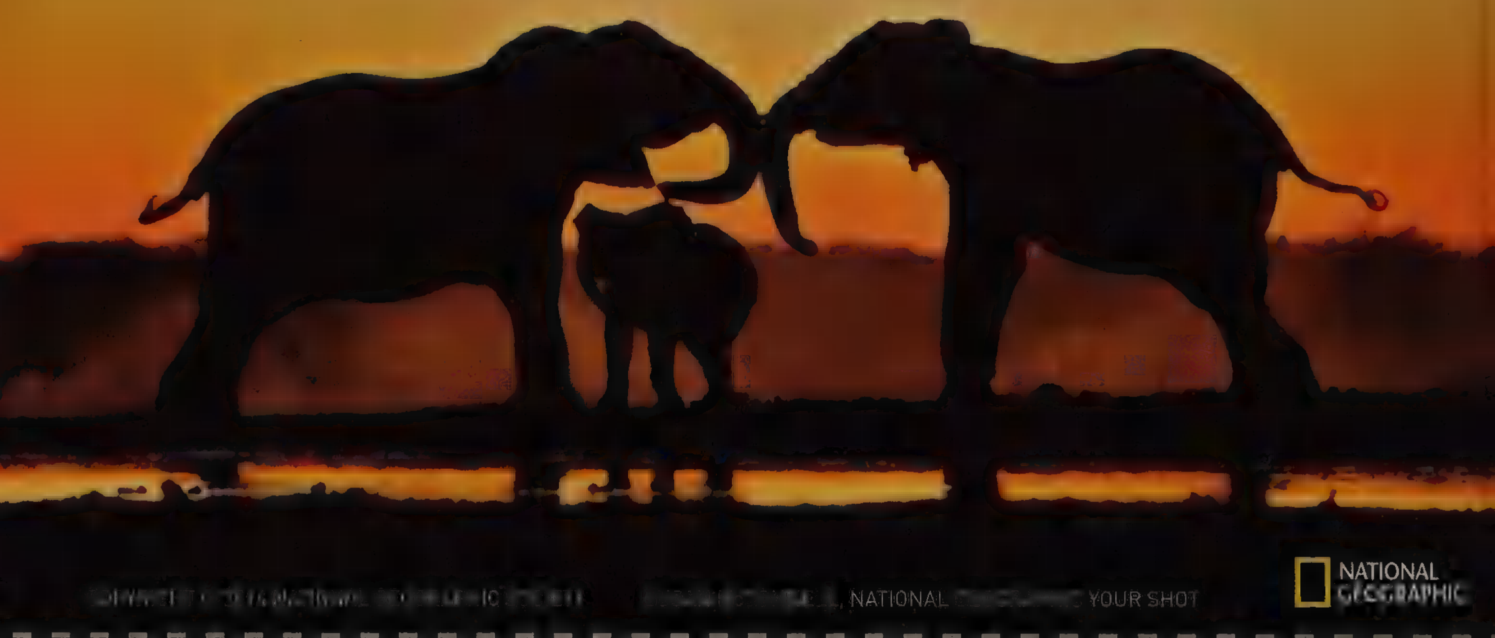

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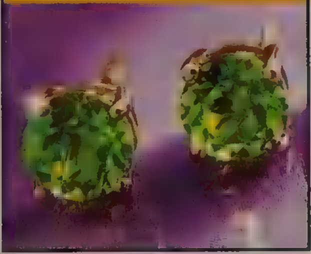

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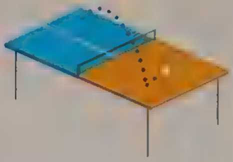

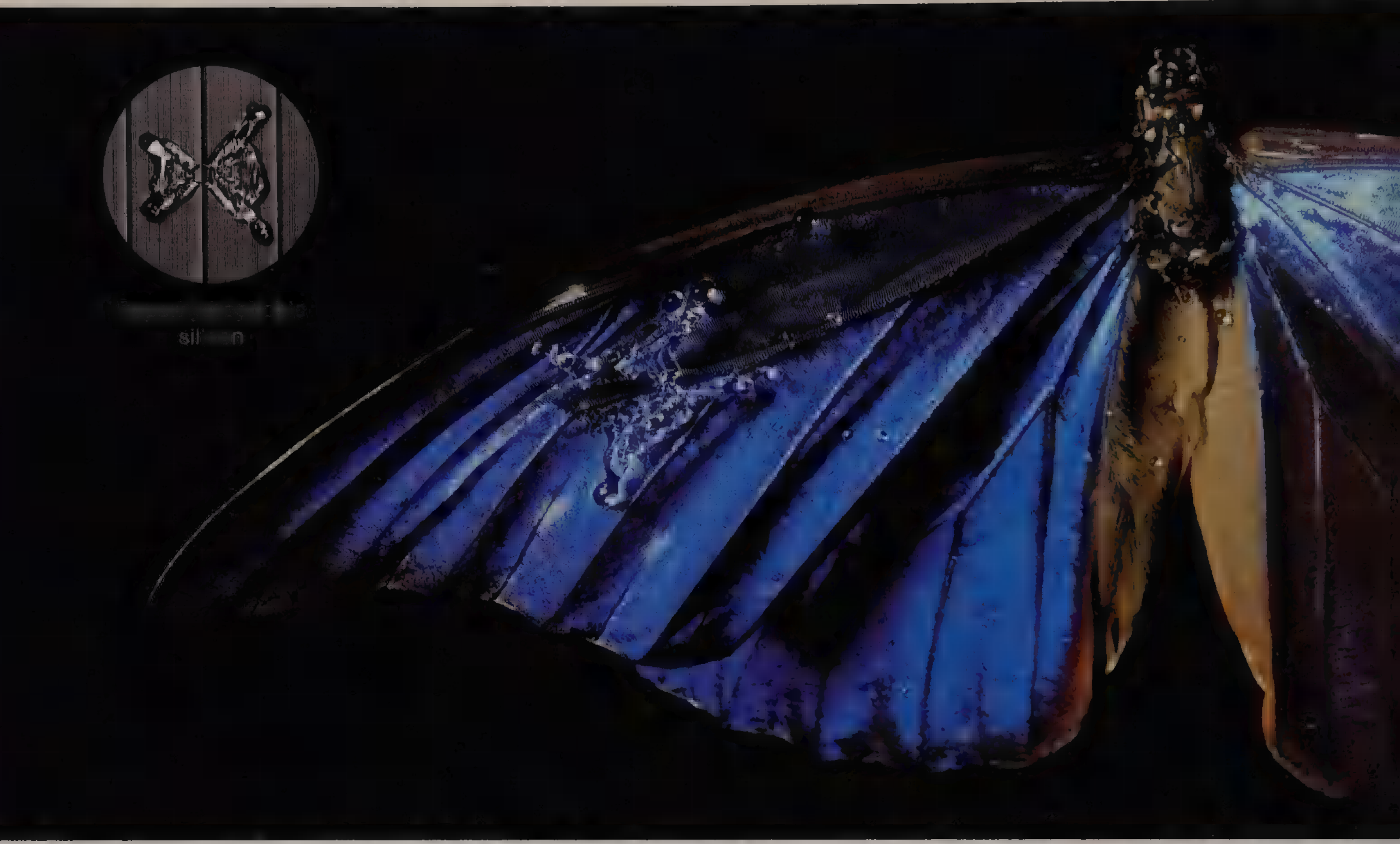

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Waterproof Wings

The wings of butterflies don't just help the insects fly. They also repel water. The wings do it so well, in fact, that an international team of engineers now sees them as models for how future airplanes could be made. Moisture makes flight less efficient. Ice is even more of a drag. A butterfly's wings, with their intricate ridges and waxy covering, can buck a water droplet 40 percent faster than the famously hydrophobic lotus leaf.

Every millisecond is important. "If we can reduce the contact time with water, a surface can stay dry longer," says MIT's Kripa Varanasi. That would mean faster flights and less need to spray de-icing chemicals, which in 2013 delayed thousands of U.S. flights. If the idea takes wing, it won't be the first time humans have taken a page from nature's efficient playbook. *—Daniel Stone*

Cheese Fix There's a [redacted] [redacted] love cheese. [redacted] contains tiny amounts of potentially addictive substances. Some of the feel-good chemicals come from casein, [redacted] milk protein that's concentrated during cheesemaking. Our digestion breaks down casein, creating morphine-like chemicals called casomorphins. But that's not all. Milk may also include traces of morphine itself, produced [redacted] the cow's liver. Such natural drugs are likely beneficial to calves for two [redacted] They have [redacted] calming effect, and they hook the calf [redacted] milk, compelling [redacted] to [redacted] [redacted] it gets all the nutrition [redacted] needs. *—A. R. Williams*

PHOTOS: KYLE HOUNSELL, ADAM PAXSON, JAMES BALES, JAMES BIRD, AND KRIPA VARANASI (TOP); JAMES BIRD, HYUK-MIN KWON, RAJEEV DHIMAN, ADAM PAXSON, AND KRIPA VARANASI (INSET); WILL HEAP, DORLING KINDERSLEY/GETTY IMAGES. ART: ÁLVARO VALIÑO

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Caped Crusade

"Bullfighting is the only art in which the artist is in danger of death," wrote Ernest Hemingway. Now the art itself seems to be in danger. The number of *corridas* held each year in Spain is down 67 percent since 2007; unemployed matadors are leaving for Latin American arenas, and the region of Catalonia has banned the centuries-old spectacle.

Like the bull stabbed multiple times in the ring, bullfighting suffers from many wounds. Nationalists in the country's autonomous regions reject bullfighting as too Spanish, while animal rights groups say it's too cruel. The deepest wounds come from Spain's economic crisis. "If you are unemployed," says Vicente Royuela, an economist at the University of Barcelona, "you aren't going to a bullfight." Last year, after 590,000 Spaniards signed a petition, the government granted bullfighting cultural heritage status to prevent further regional bans. When the economy recovers, says Royuela, "I have no doubt bullfighting will be back again." *—Rachel Hartigan Shea*

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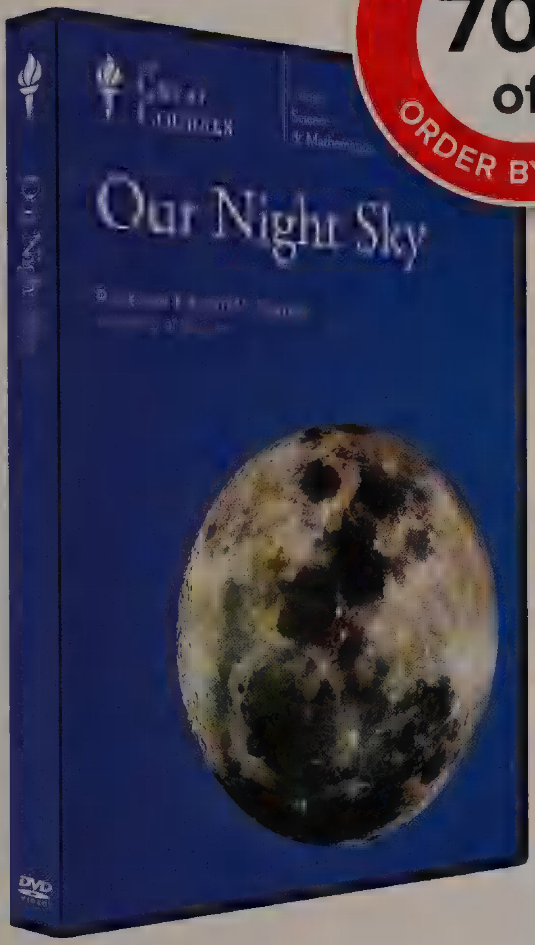

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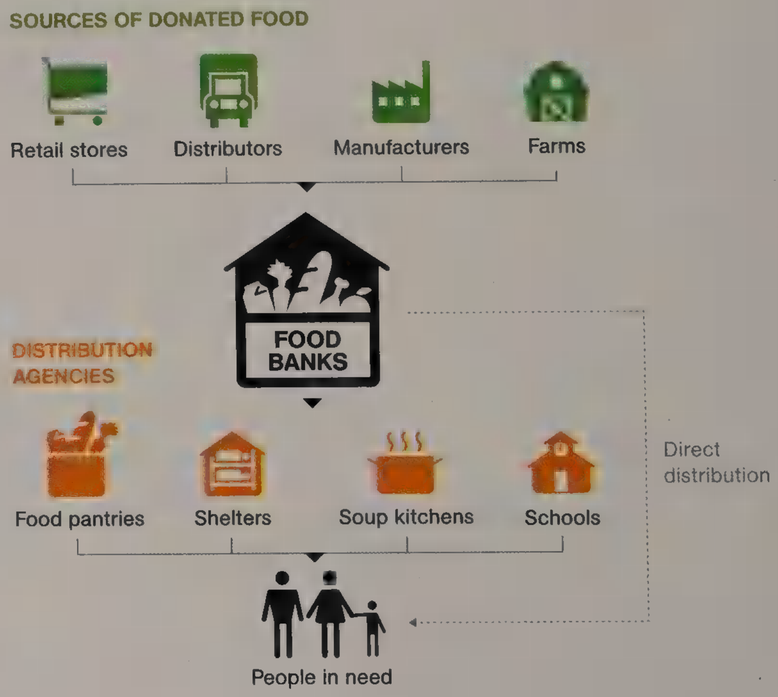
Volunteers pick apricots in downtown San Jose, California, to donate to food banks and other charities.

Food Banks

In the late 1960s in Phoenix, Arizona, John van Hengel heard a woman say that she relied on grocery store Dumpsters to find food for her children. She gave him an idea: create a place where food could be deposited and withdrawn, as at a bank.

"It upset him to see usable food go to waste," says Ross Fraser of Feeding America, the network of more than 200 food banks that grew from van Hengel's first warehouse. The group now helps feed one in eight Americans. Food banks are also on the rise globally. "We are seeing a new face of hunger," says Fraser. "There are Ph.D.'s on food stamps." *—Eve Conant*

WASTE NOT Food collected would otherwise be discarded.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Distributors
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FOOD BANKS
DISTRIBUTION AGENCIES
Food pantries
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Schools
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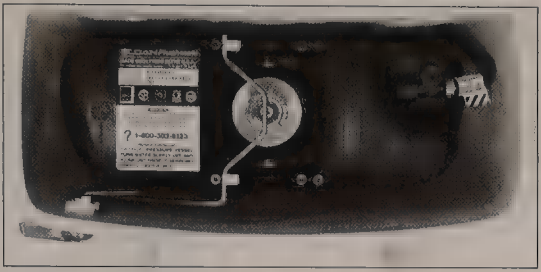

You could get money from an $18 million Flushmate Settlement

A Settlement has been reached in a class action lawsuit about the Series 503 Flushmate III Pressure Assist Flushing System ("Flushmate System"). You may be eligible for cash payments from a proposed $18 million Settlement. The money compensation is in addition to the Flushmate System recall remedy you may have received and may request from Flushmate as part of its recall program.

Who's Included?

The Settlement includes anyone who owns or owned a toilet with a Flushmate System manufactured from October 14, 1997 through June 30, 2009. Flushmate Systems were installed in various toilet brands sold at Home Depot and Lowe's stores and through distributors and plumbing contractors.

Installed in: American Standard, Crane, Ecotech, Eljer, Gerber, Kohler, Mancesa, Mansfield, Orion, St. Thomas, Universal Rundle, Vitra, Vitromex and Western Pottery toilets.

What does the Settlement provide?

Subject to Court approval, and to the extent not previously reimbursed, Class Members can receive a distribution from the Settlement Fund for having installed: (1) a Flushmate Repair Kit, (2) a replacement pressure vessel, or (3) a replacement toilet. Depending on the number of qualified claims, it is possible that Class Members will receive less than the full amount of their out-of-pocket expenses. To the extent not previously reimbursed, Class Members can also receive reimbursement for any direct property damage caused by a Flushmate System that leaked or burst. Any money left in the Settlement Fund after two years will be divided among Class Members who file valid claims or will be donated to a charitable organization.

How can I get a payment?

File a claim online at www.FlushmateClaims.com or call 1-877-412-5277. (For questions related to the Flushmate Recall, please visit www.flushmate.com or www.flushmate.com/recall.)

What are my rights?

Even if you do nothing you will be bound by the Court's decisions. If you want to keep your right to sue the Defendants yourself, you must exclude yourself from the Settlement Class by **July 25, 2014**. If you stay in the Settlement Class, you may object to the Settlement by **July 30, 2014**.

The Court will hold a hearing on **August 25, 2014** to consider whether to approve the Settlement and a request for attorneys' fees of up to 25% of the Settlement Fund, plus reimbursement of attorneys' costs and expenses. You or your own lawyer may appear at the hearing at your own expense.

For more information or a Claim Form:

1-877-412-5277 or www.FlushmateClaims.com

How to Outsmart a Millionaire

Only the "Robin Hood of Watchmakers" can steal the spotlight from a luxury legend for under $200!

Mr. Bigshot rolled up in a roaring high-performance Italian sports car, dropping attitude like his $14,000 watch made it okay for him to be rude. That's when I decided to roll up my sleeves and teach him a lesson.

"Nice watch," I said, pointing to his and holding up mine. He nodded like we belonged to the same club. We did, but he literally paid 100 times more for his membership. Bigshot bragged about his five-figure purchase, a luxury heavyweight from the titan of high-priced timepieces. I told him that mine was the ***Stauer Corso, a 27-jewel automatic classic now available for only $179.*** And just like that, the man was at a loss for words.

The Stauer *Corso* is proof that the worth of a watch doesn't depend on the size of its price tag. Our factory spent over $40 million on Swiss-made machinery to insure the highest quality parts. Each timepiece takes six months and over 200 individual precision parts to create the complex assembly. Peer through the exhibition back to see the 27-jeweled automatic movement in action and you'll understand why we can only offer the ***Corso*** in a limited edition.

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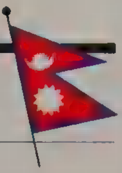
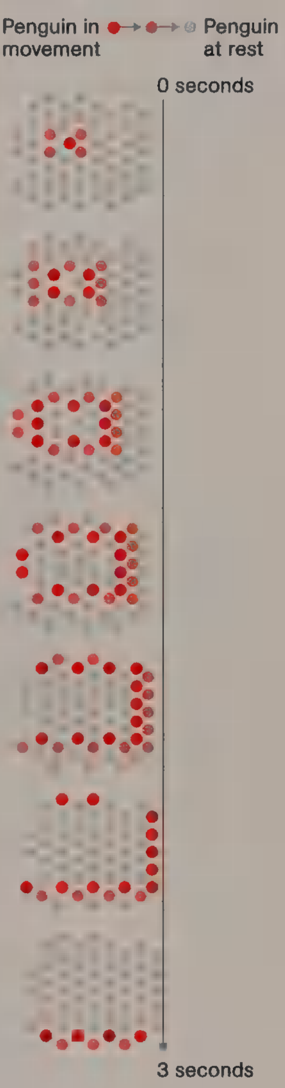
Nepal is currently the only country that does not have a rectangular or square flag.



DOING THE WAVE
Waves of movement restore ideal spacing between neighboring penguins.



Crowd Control

On the world's most barren continent emperor penguins opt to sit in traffic. Why? Antarctic temperatures plunge as low as -60°F, so a tight huddle helps incubating male birds stay warm and conserve energy. Unlike human traffic jams, however, in which each person is an individual actor, the penguins act as a unit. A group of international researchers discovered last fall that when one bird moves even a few inches, it triggers waves of motion in every direction as the rest of the penguins adjust.

Other birds flock together too, as do schools of fish. "What makes emperors different is that they try to limit the space between them [for heat]," says University of Erlangen-Nuremberg physicist Richard Gerum. His model of penguin huddles (right) may one day help human traffic flow better. Mimicking how a penguin moves—and how its neighbors compensate in response—could lead to a future where driverless cars speed along just inches apart. *—Daniel Stone*

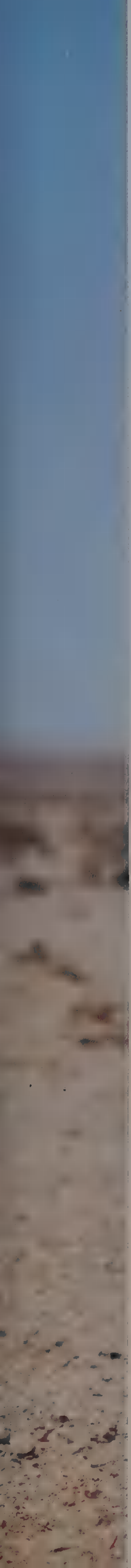
Tear Factor

Most people can't chop an onion without crying. That's because of something called the lachrymatory factor: a tear-inducing compound onions unleash when cut. In nature, says organic chemist Eric Block, this is likely a defense against predators. In the kitchen, it's a nuisance. So scientists from Japan and New Zealand have created a "tearless" variety by suppressing the enzyme that triggers the irritant. The genetically modified bulbs (left) are strictly for study, but the goal is to breed an edible version naturally. That would be a sight for sore eyes. *—Catherine Zuckerman*

PHOTOS: DAVID TIPLING (PENGUINS); KEVIN MIYAZAKI, REUTERS. ART: ÁLVARO VALIÑO (TOP)
GRAPHIC: LAWSON PARKER, NGM STAFF. SOURCE: RICHARD GERUM, UNIVERSITY OF ERLANGEN-NUREMBERG

THE DOGS OF WAR

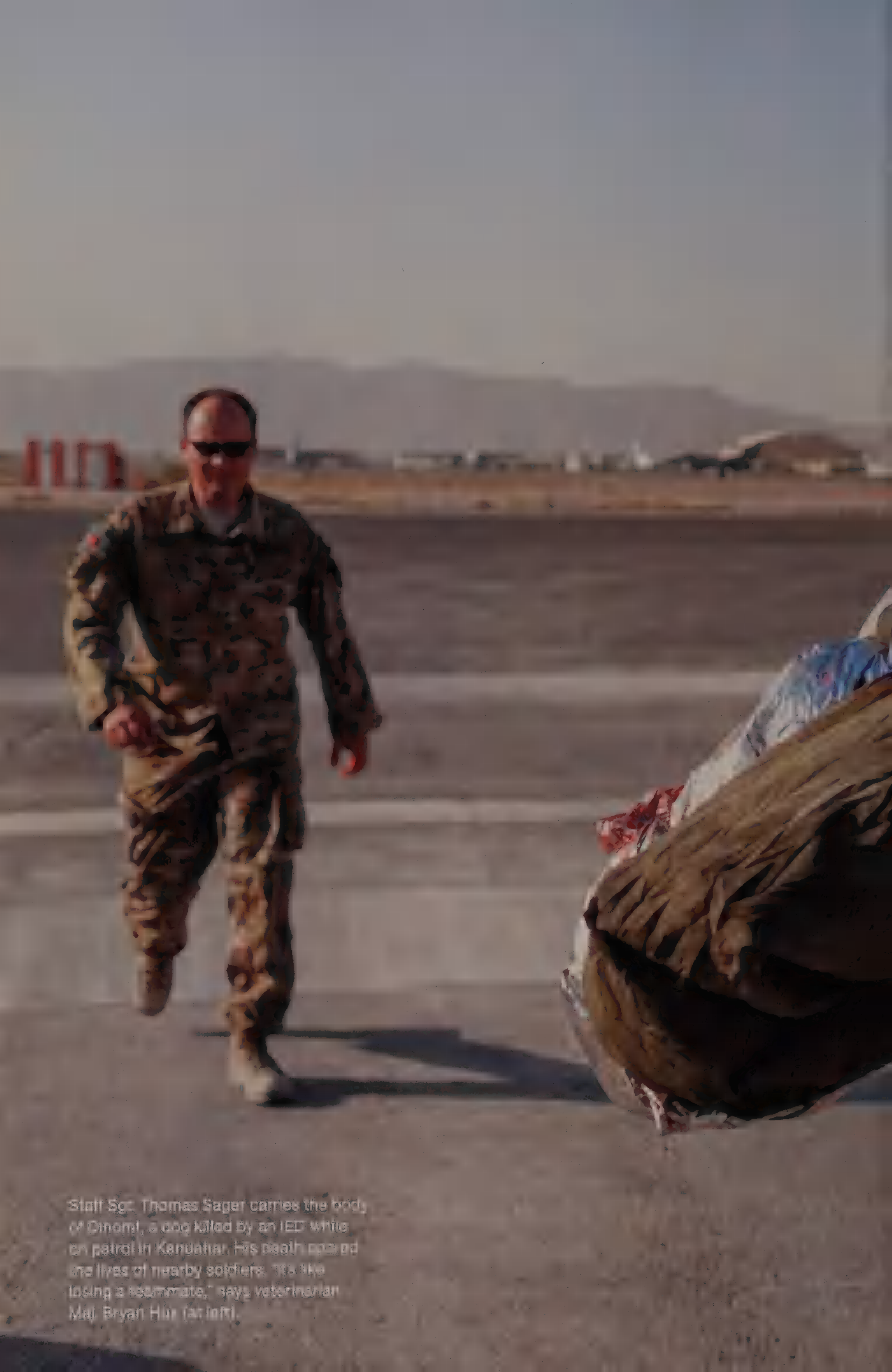
OUT IN FRONT OF AMERICA'S TROOPS, COMBAT CANINES AND THEIR HANDLERS LEAD THE WAY ONTO THE MOST DANGEROUS BATTLEFIELDS ON EARTH.



Marine Cpl. John Dolezal poses with Cchaz, a Belgian Malinois, at Twentynine Palms in California. Dogs bred at Lackland Air Force Base in Texas, the military's primary canine facility, are given names that begin with a double letter.

Army Staff Sgt. Terry Young and his German shepherd, Wero, search for explosives at a checkpoint in Kandahar, Afghanistan. More than 600 U.S. military working dogs are deployed worldwide at any given time.

MP



Staff Sgt. Thomas Sager carries the body of Dinomi, a dog killed by an IED while on patrol in Kandahar. His death spared the lives of nearby soldiers. "It's like losing a teammate," says veterinarian Maj. Bryan Hux (at left).

BY MICHAEL PATERNITI PHOTOGRAPHS BY ADAM FERGUSON

HERE IS MARINE CORPORAL JOSE ARMENTA

in his tent on the night before getting blown up in Afghanistan. He jokes with Mulrooney and Berry and the medic the guys have nicknamed "Christ." He feeds and waters his dog, Zenit, a sable-coat German shepherd. He lets Buyes, who will be dead in three months, ruffle Zenit's fur, for the radioman is crazy about the dog. Then he takes Zenit outside in the waning light of this dusty, desert otherworld to train.

They're happiest like this. Jose has Zenit sit, which the dog does obediently, and then Jose jogs 50 yards down and hides a rubber toy, a Kong, up against a mud wall, covering it with dirt. On Jose's command, Zenit bursts forward, zigging in search of it, tail wagging. It's an intricate dance. Voice commands met by precise canine action, always with the same end goal in mind—to find the toy. Tomorrow, on patrol, the objective will be finding not a toy but an improvised explosive device, or IED, one of the Taliban's most brutally effective weapons against American troops here in what many consider the most dangerous province in one of the world's most dangerous countries. And no dog can find every bomb every time.

For the past three months Jose's been stationed at Patrol Base Alcatraz, at the edge of a town called Sangin in Helmand Province, without a "find." Despite his optimism—the man always beams a disarming smile—the lack of finds is beginning to wear on him almost as much as the 100-degree heat, which feels even hotter rucking 75 pounds of gear.

As a Marine dog handler, Jose is a perpetual outsider, assigned to platoons that have been together for years, tight-knit combat brotherhoods that regard newcomers, especially dog handlers, with a high degree of circumspection. His job is to accompany that platoon, to clear a path through hostile territory for his fellow marines. But as thankful as they may be, Jose

American GIs treat a combat dog wounded in the battle for Guam during World War II.

knows it's natural for them to wonder: Is this guy any good? Will he fit in? How will he respond in that first firefight?

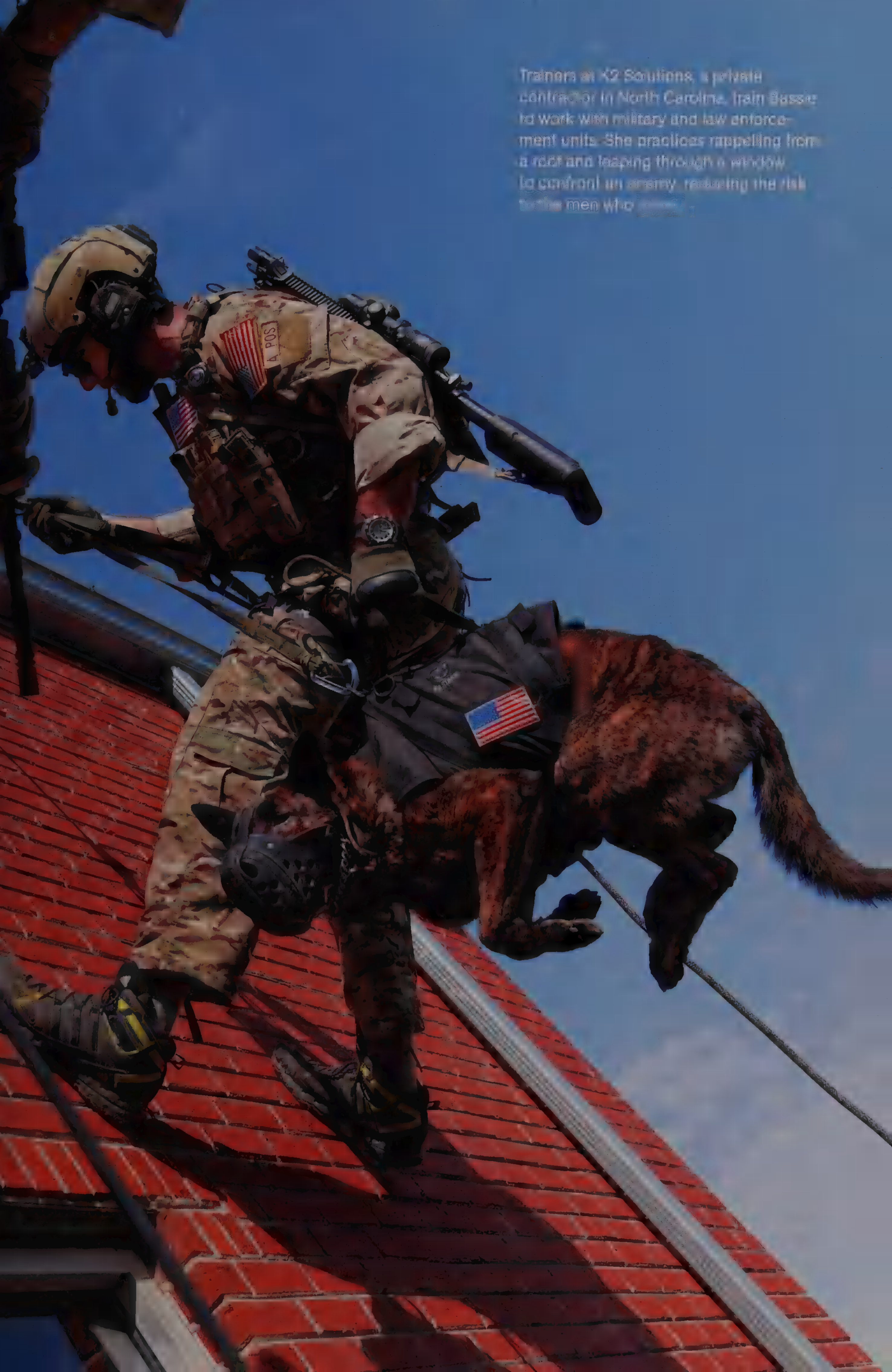
At this moment in August of 2011 the stated mission in Sangin is to secure the 320-foot-high Kajaki Dam, to keep the Taliban from blowing it up and flooding the Helmand Valley. The marines of Third Recon, in groups of a dozen or so, take turns disrupting the enemy, mapping active pockets of Taliban fighters. Jose and Zenit are asked to accompany practically every mission. Each time he and Zenit go out beyond the wire, they're walking point along with a marine carrying a metal detector, making themselves the first targets as Zenit scours the area for any whiff of nitrate that might signal a buried IED. As exhausting as it is, Jose always says yes.

Maybe there's a little chip on Jose's shoulder, or maybe he feels there's a lot to prove—to himself, to the marines of Third Recon, and to his family back home. Maybe he's just doing his job, or maybe he needs just one find to allay whatever doubts he harbors about his—and Zenit's—ability to do the job. In this place especially, the threat is palpable. Sangin is littered with IEDs and teeming with enemy fighters tucked behind thick mud walls. It's where British forces, before pulling out of Sangin altogether in 2010, lost more than a hundred troops. It's been a graveyard since for many Americans, and a place where numerous U.S. troops have received disfiguring injuries.

This is what a dog handler tries not to dwell on: the risk associated with the need to find bombs and with the possibility of missing one.

W. EUGENE SMITH, TIME & LIFE PICTURES/GETTY IMAGES

Handlers in training at Lackland Air Force Base in San Antonio must learn basic leash skills and hand signals before they start working with a dog. Until then a used ammunition can stands in for the canine.



Trainers at K2 Solutions, a private contractor in North Carolina, train Bassie to work with military and law enforcement units. She practices rappelling from a roof and leaping through a window to confront an enemy, reducing the risk to the men who [illegible].

On base you sometimes hear them go off in the distance, set off by a goat, an unsuspecting villager. Sometimes frantic locals will rush a bleeding kid up to Alcatraz for medical help. And the recent news about two fellow dog handlers, Jeremy and Jasco, in his deployment, has been bad. Both were blown up and lost their legs. Jose is clear about this: He'd rather die than lose a limb or some vital body part. He'd rather get waxed than be half a person. What you do to take your mind off the fear is just what Jose does now, as he has done for the past two years: You train your dog, do your job, leave the rest to fate.

The next morning, August 28, Third Recon knows that the Taliban have been busy. Alcatraz sits on a rise out in the cornfields, not far from a wadi, and intel has it that IEDs have been planted everywhere. "We knew someone was going to get hit on that mission," Sgt. Ryan Mulrooney will say later. "Every day something was getting blown up. We knew going in there that it was a pretty risky movement."

So for the first time since deploying to Afghanistan, Jose puts on his "blast briefs," underwear made of Kevlar material to limit genital injuries, and he mounts his helmet cam hoping to document his first find. Then he puts an IV in Zenit to keep him hydrated in the heat.

The team moves out at 10 a.m. in ranger file, and Jose guesses it's already 120 degrees. The marines work down the hill slowly, and when they hit the 611 highway, Jose feels a surge of adrenaline. His mouth goes cottony as he commands Zenit, orchestrating the dog's every movement. The team veers through the corn to avoid the road, until they hit the wadi that runs parallel to the highway, eight feet deep and ten feet wide, empty of water.

Jose guides Zenit from bank to bank. Mulrooney, working the metal detector, calls out, "I think I got one here." Jose approaches, looks at the humped, loose dirt with a wire showing, fixes Mulrooney with a smile, and says, "Yup."

Michael Paterniti wrote about Hong Kong in the June 2012 issue. This is photographer Adam Ferguson's first assignment for the magazine.

Marine Gunnery Sgt. Kristopher Knight conditions Ronnie to the sound of gunfire at Yuma Proving Ground in Arizona, so that the dog will learn to remain calm during a firefight. Some trainers don turbans, play calls to prayer, and bring in farm animals to prepare dogs for the sights, sounds, and smells of Afghanistan.

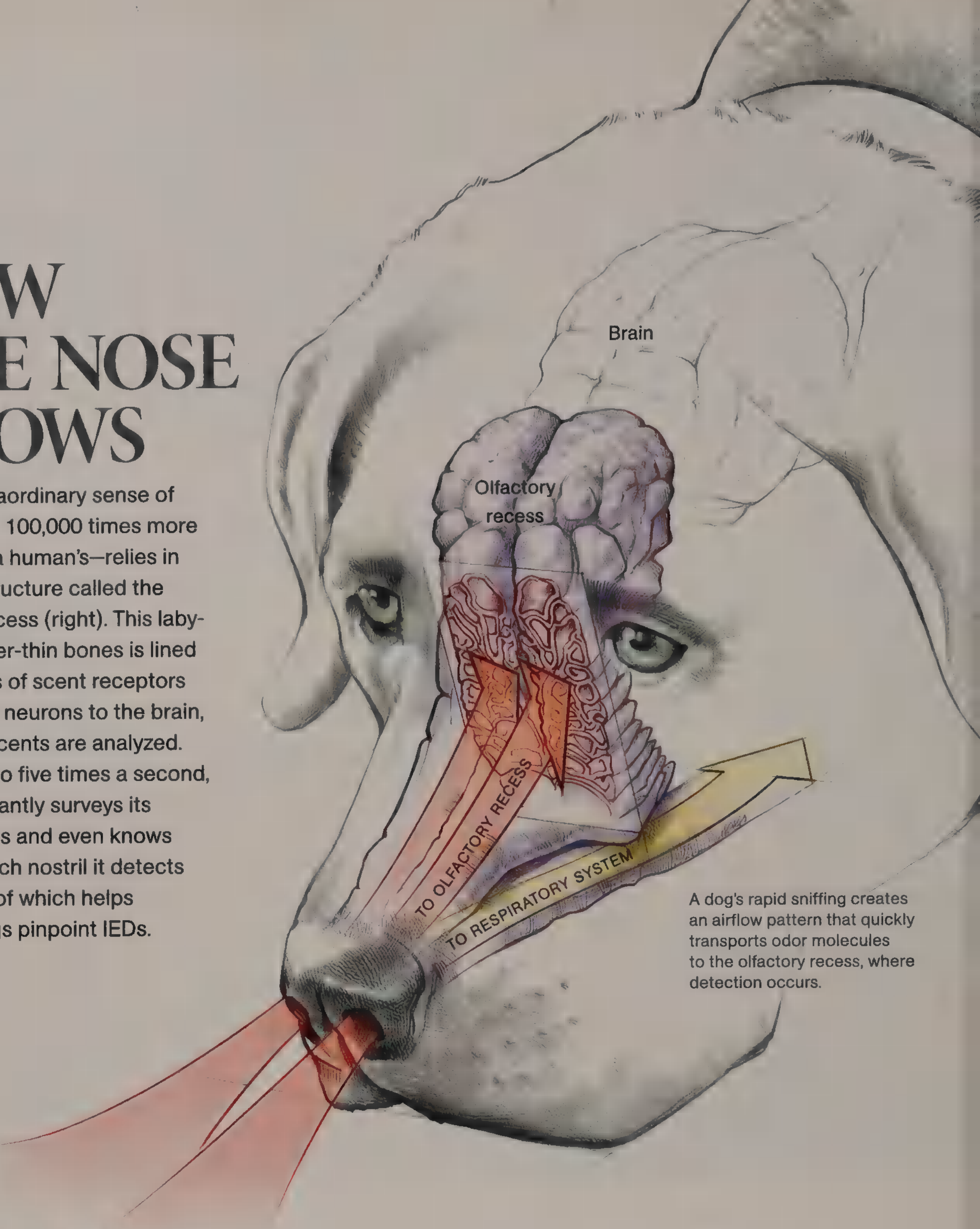
The team leader is notified. Jose moves on, spies another device, and calls it out. Sensing a pattern, he sends Zenit to the far side of the wadi, where the dog freezes, tail wagging, nose suddenly working overtime. The change in behavior marks the spot. After nearly a hundred days out here, it's their first IED as a team.

In his mind Jose throws an invisible high five and lets out a silent whoop. Trainers say, "Emotion runs through the leash." Jose knows he needs to remain calm, to keep Zenit focused, but how can he not be excited? The team leader is notified again. Jose and Zenit continue down the wadi in the deathly heat. The sun blisters down on the men in formation slow-walking in each other's footsteps, using shaving cream to mark safe spots. Just like that, three in a row. The riverbed is full of explosives—but where's the next? With that question, Jose's elation gives under the weight of duty. He and Zenit are the ones responsible for finding out.

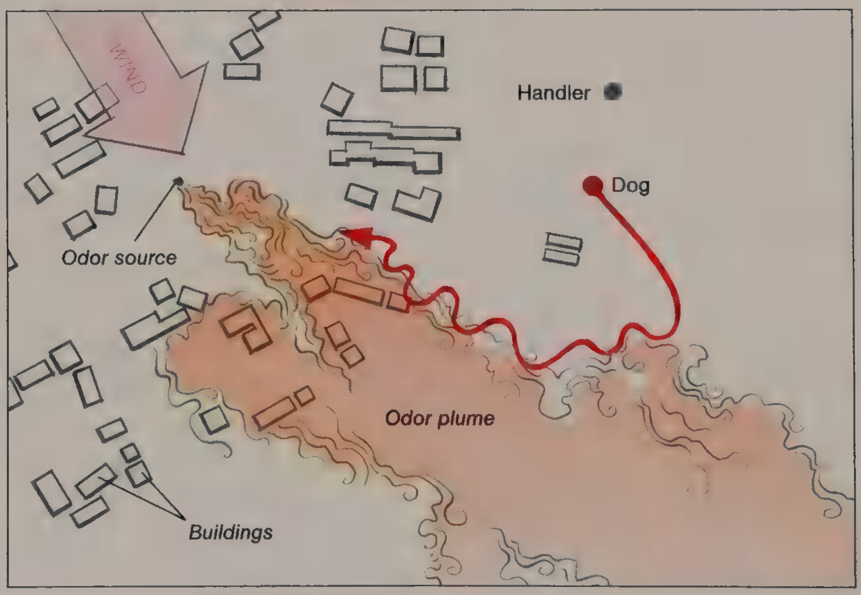
ZENIT—A 78-POUND German shepherd with an irrepressible love for ball retrieval—was born on Halloween, 2007. He was bred by a private contractor in Europe, who gave him his odd name (pronounced ZEE-nit), the meaning of which, if there was a meaning, Jose never learned. Having passed a battery of medical tests, Zenit was procured by the U.S. military just after his first

HOW THE NOSE KNOWS

A dog's extraordinary sense of smell—up to 100,000 times more acute than a human's—relies in part on a structure called the olfactory recess (right). This labyrinth of paper-thin bones is lined with millions of scent receptors attached by neurons to the brain, where the scents are analyzed. Sniffing up to five times a second, a dog constantly surveys its surroundings and even knows through which nostril it detects a scent. All of which helps combat dogs pinpoint IEDs.



A dog's rapid sniffing creates an airflow pattern that quickly transports odor molecules to the olfactory recess, where detection occurs.



Mission: Find IEDs
Various chemicals are used to make IEDs. Training exercises developed by the U.S. Office of Naval Research teach dogs to follow IED odor plumes to a source hidden by buildings (left). The dogs work off leash, so their military handlers learn to direct them to hunt upwind. On field patrol a dog zigzagging to investigate odors may cover up to three miles for every mile its handler walks.

JASON TREAT, NGM STAFF. ART: BRUCE MORSER
SOURCES: OFFICE OF NAVAL RESEARCH, NAVAL RESEARCH LABORATORY; K2 SOLUTIONS; BRENT A. CRAVEN, PENNSYLVANIA STATE UNIVERSITY

birthday and shipped to the kennel at Lackland Air Force Base in San Antonio. There working dogs are initially trained by the 341st Training Squadron in "drive building, grip development, and environmental and social stability," according to the Department of Defense. Days are regimented, the dogs released only at allotted hours for food and water, exercise, and training. It's during these training sessions that the marines evaluate what role a dog is best suited for: patrol, detection, or tracking. Though the military resists discussing individual dogs, records indicate that Zenit spent 13 months in the Lackland kennels. Because dogs have short attention spans, his lessons would have lasted up to an hour or two each day, with some as short as three to five minutes at a time. At the course's end Zenit was certified for explosives detection and patrol.

Yet when the two-year-old Zenit was finally paired with Jose on Okinawa, Japan, in 2010, the dog was still very much raw material. Having been passed over for deployment with his previous dog, Jose felt extra pressure to succeed with Zenit.

Not all military dogs are suited to combat. Some wither in the heat or become too excited by the sounds of gunfire or explosions, even after they've been desensitized to them in training. Some are too loyal, too lazy, or too playful. Each dog is its own particular, sometimes peculiar, universe. Still, certain breeds generally do better than others on the battlefield, such as German shepherds, Labrador retrievers, and especially the Belgian Malinois, which is known for being fearless, driven, and able to handle the heat.

But what works in a given environment may not work in another. History suggests that each battle situation calls for its own breed and tactics. Benjamin Franklin encouraged the use of dogs against the Indians. They "will confound the enemy a good deal," he wrote, "and be very serviceable. This was the Spanish method of guarding their marches." (Spanish conquistadores were said to have used bullmastiffs against Native Americans.)

During the Second Seminole War, starting in 1835, the U.S. military used Cuban-bred bloodhounds to track Indians in the swamps of Florida. Dogs were said to have guarded soldiers in the Civil War. During World War I both sides used tens of thousands of dogs as messengers. In World War II the U.S. Marines deployed dogs on Pacific islands to sniff out Japanese positions. In Vietnam an estimated 4,000 canines were used to lead jungle patrols, saving numerous lives. (Nevertheless, the military decided to leave many behind when the U.S. pulled out.)

At the height of the wars in Afghanistan and Iraq, the U.S. military had a force of roughly 2,500 military working dogs (MWDs). Some have entered our national lexicon as heroes in their own right: Cairo, a Belgian Malinois hailed for his work with the Navy SEAL team that killed Osama bin Laden. And Rex, a shepherd; his handler, Mike Dowling, wrote a book about their harrowing exploits in Iraq, saying, "It was Rex who gave me the strength to get up and to carry on."

This age-old bond between man and dog is the essence of our fascination with these teams: The human reliance on superior animal senses—dogs are up to 100,000 times more alert to smells than humans are. The seriousness of the serviceman's endeavor, in contrast to the dog's heedless joy at being on the hunt or at play. The selflessness and loyalty of handler and dog in putting themselves in harm's way—one wittingly and one unwittingly—to save lives.

The image of dog and marine living as Lassie and Timmy, however, is not entirely accurate. In general, the military bureaucracy regards a working dog as a piece of equipment, something Jose understood the first time he saw Zenit's ID—N103—tattooed in his ear. After their training sessions in Okinawa, Jose always returned Zenit to his kennel according to protocol, and he knew it was vital that he establish himself as the alpha in tone and action. "Dogs are like toddlers," says Marine Gunnery Sgt. Kristopher Knight, who trained Jose and Zenit at Yuma Proving Ground in Arizona. "They need to be told what to do. They need to know that their primary drives—oxygen, food, water—are taken care of. Two betas will never get it right. One

Army Staff Sgt. Jason Cartwright has his Labrador retriever, Isaac, sniff for weapons and explosives in a basement in Kandahar. A dog is trained to sit or lie down and not bark when it locates a target scent. The handler rewards the dog by letting it chew on its toy.

Sergeant Cartwright bonds with Isaac during a mission to disrupt a Taliban supply route. Dogs are very sensitive to their handlers' emotions. Says Jay Crafter, a trainer for the military, "If you're having a bad day, your dog is going to have a bad day."

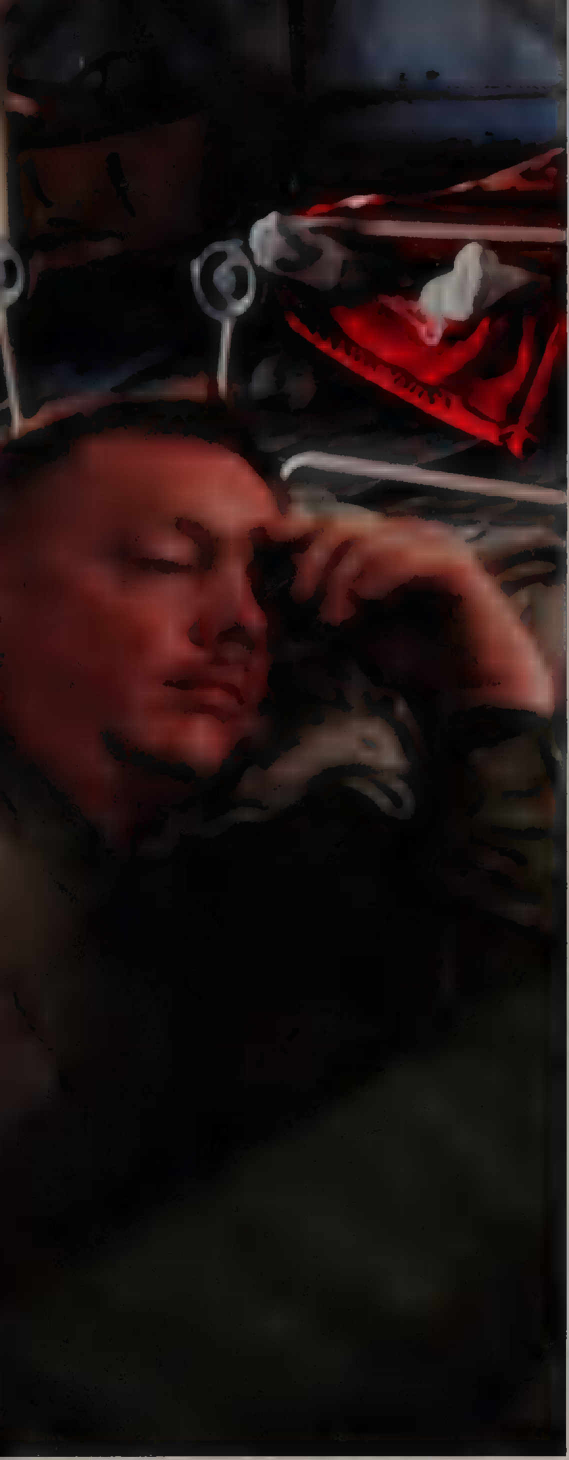
CARTWRIGHT
U.S. ARMY

must be the alpha, and it must be the handler."

The truth was, until Afghanistan and that August day in 2011, Jose would have repeated the party line. If Zenit stepped on an IED and was killed, Jose was pretty sure he wouldn't have shed a tear. Theirs was a strictly professional relationship and needed to remain that way. If Zenit got blown up, Jose would start all over again with another dog.

JOSE ARMENTA GREW UP TOUGH, simply because nothing came easy. His family lived in East Los Angeles, where his parents were affiliated with gangs and split up when Jose was young. His mother, who was of Puerto Rican heritage, cared for the children as best she could; his father, of Mexican origin, came and went. One of Jose's earliest memories is of the car accident that spared him and killed his little sister. He was five; she, four. The rent was often overdue, and sometimes his family simply jumped to another house, another school—15 in all. He was always the new kid, the outsider. In high school he lived in his garage, cranking heavy metal. He played drums in a band. He wore his hair in a Mohawk and pierced his nose.

But even the extremes of Jose's rebellion were relatively tame: ditching class, drinking beer, smoking cigarettes, playing video games. Living in a violent world of real and wannabe gangsters,



Air Force Staff Sgt. Jonathan Bourgeois clips Oopey's toenails before a mission in Afghanistan. Handlers care for their dogs' every need, learning canine CPR as well as how to spot canine post-traumatic stress disorder, which afflicts some 5 percent of deployed dogs.

of random shootings, of drug dealing, he wanted to escape. What he wanted most was the opposite of that world: He wanted to be a marine.

In July 2007, at 18, he enlisted and found himself at Camp Pendleton. Having grown up rootless and without religion, he immediately fell in love with the military's sense of tradition and ritual. He was nicknamed "Socks," for his civilian uniform of baggy shorts and tube socks pulled up to the knee. Upon graduating from boot camp, he signed up for military police training and was eventually assigned to the U.S. base on Okinawa. As a class standout, he was also offered the chance to go to Lackland to begin training as a dog handler.

Jose had always loved dogs. During his erratic upbringing, they'd been ballast. At various times he'd owned a Dalmatian, a pit bull, and a Pekingese-chow chow mix named Bandit, legendary for once biting a friend on the posterior. But Jose understood that a military dog was an instrument he had to master, just as a technician had to understand sonar on a submarine or a drone operator had to learn to control a Predator.

The military, with its sharp edges and unyielding discipline—the thing that was saving him from the streets and his parents' life—seemed a little more humane in those moments when he was rewarding a dog by roughing its neck fur or giving it some fawning praise. Though he instantly loved the work, he was also inspired by its higher purpose. One bomb found in the field might equal several lives saved.

Jose's first impression of Zenit was that he seemed too sweet and a little unruly, still full of puppy energy. Jose already had a dog, a Malinois, but he was eager to try a shepherd and picked out Zenit himself.

A new working dog in the Marines learns to search for IEDs in small, incremental steps. After mastering basic obedience, the dogs are taught to recognize a range of odors associated with explosives, including ammonium nitrate, which is used in the majority of IEDs in Afghanistan.

Then they begin to practice an exercise known as "birding," which is designed to let the handler direct the dog's movements from a distance.

After several combat tours Kimberley, a retired detection dog, has a new family in Texas. Many former military dogs are put up for adoption, with federal agencies, local law enforcement and former handlers given priority. The wait for a dog is a year to 10 months.

First a handler unleashes the dog and orders it to move toward a hidden "bird launcher," a remote-controlled catapult loaded with a tennis ball. Adherence to voice commands and hand signals is crucial and often hard-won. When the dog comes close to the launcher, the handler triggers it, and the ball rockets into the air. The dog gives chase and returns the ball to the handler, who praises and pats the dog.

As the dog gets better at following directions, the handler begins hiding items scented with all types of explosive materials in the surrounding terrain. By constantly moving the launcher and spreading scents both near and far, the dog becomes adept at searching large areas and alerting the handler to everything that smells like an explosive.

Eventually there's no bird launcher, no tennis ball, just the scents. After finding each one, the dog is called back and rewarded with the Kong. And that's what the process boils down to for a dog. An IED search is a game—identify a scent and get a toy.

Zenit was a motivated seeker—and perfect partner. In the fall of 2010 the pair was selected for deployment and sent to Yuma Proving Ground for a final three-week, boot-camp-like crystallization of everything a handler and a dog need in a war zone and for one final test to prove they are ready. In a fake Afghan village a handler and his dog must search out a complicated array of IEDs. Some are scented for the dog to find. Others are unscented but left exposed for the handler to spot. If together they find more than 80 percent, the pair receives final approval to go "downrange."

"Jose was a bit of an East L.A. hood rat when he came into the corps," says one of his supervisors, Sgt. Alfred Nieto. "But he and Zenit really knew what they were doing—that wasn't in doubt. I think they grew up a lot together."

After passing the training course at Yuma, the two boarded a transport, spent one night in Germany, and then flew to the Marines' main base, Camp Leatherneck, in Afghanistan. From there Jose and Zenit were sent to Alcatraz. One moment they were in a fictional Afghan village in the desert of Arizona, the next they were in a real one, in Helmand Province, on their own.

NOW IT'S THREE MONTHS LATER. They're in the wadi outside Sangin surrounded by IEDs. The finds are rapid-fire, oscillating between Mulrooney and Jose and Zenit. *I got one... Over here... Yup.*

Two years of training with your dog, three months in-country, every day with Zenit at your side, eating MREs, packing your gear—and your dog's—humping, working, waiting, waking at midnight to make sure Zenit pees and poops in the designated spot, and suddenly everything, your life as a soldier and handler, your life as hood rat and outsider and striving human being, gets compressed into 15 minutes and 60 yards.

Jose believes he's onto the pattern. It seems the Taliban have buried IEDs at the access points to the wadi, assuming the troops would feel safer out of sight down in the dry riverbed than exposed in the open fields. It's all happening so quickly now. He takes deep breaths to tame his excitement and maintain focus.

A dog's nose generally works best—or is most sensitive—in cool, calm weather. Odors become more volatile at higher temperatures, and wind can dilute and disperse them over a broad area, camouflaging their source. That's the good thing: Down here there's no wind. But it's midday, bone-dry, and so fryingly hot Jose can taste the salt of his sweat as it trickles to his lips.

Zenit is working the far bank, tuned to Jose's commands, ears perked, feet scrambling, excited too. The dog is looking for all those scents it knows will yield his toy. Where are they?

Over here a wide path leads from the berm into the wadi, and Zenit moves past it without any change in behavior. Jose follows at a distance, gauging his own steps. The men behind them follow at a distance, marking a shaving-cream route based on Jose's progress.

At the path he veers from the most trafficked area and walks up a little rise. He takes a step, then another. Which is when the earth gives, and a deafening roar fills his ears.

When his eyes open, Jose is lying on his back.

JOSE HAS LOST A LOT OF BLOOD but somehow stays conscious, asking for Zenit. The dog, 20 feet from the blast, knows something has gone wrong and lies down at Jose's side, his ears pinned to his head.

All he can see is the sky. He's been blown 20 feet back into the wadi. He knows exactly what's happening but can't comprehend any of it. His mouth is full of dirt, and his body yowls, as if on fire. He can't breathe. Mulrooney is the first to his side and cuts off his vest. Jose keeps repeating, "I fucked up. Do I still have my legs?" And then: "Where's Zenit?" Mulrooney says, "You're good, man, you're going to be fine."

There's a procedure out here when someone gets "got"—that's what the men call a hit like this. The marines secure the area; the medic puts a T-POD, a tourniquet at the waist to stanch the bleeding, on Jose; Buyes calls in a chopper; and everyone works to beat the "golden hour," the time within which the military endeavors to get a wounded soldier off the battlefield to increase his odds of survival.

But the closest chopper is already ferrying another wounded marine out of the area and takes two hours to arrive. Jose has lost a lot of blood but somehow stays conscious, asking again for Zenit. The dog, initially 20 feet from the blast, knows something has gone wrong. Zenit lies down next to Jose, his ears pinned to his head, which he lays on his paws. He stays there as they work to save Jose before the chopper arrives. According to protocol, both handler and dog are loaded on board and whisked from the spot.

A FARAWAY LIGHT—Jose remembers that. He remembers letting himself slip toward it, overcome by a very tired feeling. This was on the chopper. He remembers sensing Zenit nearby. He remembers thinking about his three younger sisters and brother (never having had role models himself, he wonders who will be theirs), his fiancée (how will she find out?), and then his sister who died (is he about to see her?). He remembers turning from the faraway light, shaking off sleep, and reentering his body.

What followed wasn't easy. He woke up in Germany, and ten days later he woke up again in Walter Reed hospital. There were 12 operations, a move to the Naval Medical Center in San Diego. Both legs had to be amputated above the knee. He slept 20 hours a day for a month. He dreamed that someone performed experiments on him with dolphins. He woke thrashing, calling for Zenit, only to learn that N103 hadn't accompanied him home, had been reassigned to a new handler, also by protocol.

"I was furious," Jose says. "And jealous. I never blamed Zenit for what happened. We were a team. If it was anyone's fault, it was my own. I just wanted my dog."

In different ways, it seemed, they were both itemized gear, until one of them didn't work anymore. Back in Afghanistan, Zenit had been returned to Camp Leatherneck, where he soon went through what's called a validation trial with another handler and then went on more than 50 foot patrols with other units. He had one more IED find.

At home, in the months after the operations, Jose waited for his incisions to heal, then worked to strengthen his core and what remained of his legs. He was given "shorties," introductory prosthetics without knee joints so he could learn to balance and stand—and get used to the pressure on his legs. Later he received prosthetics with knee joints so he could learn to walk again.

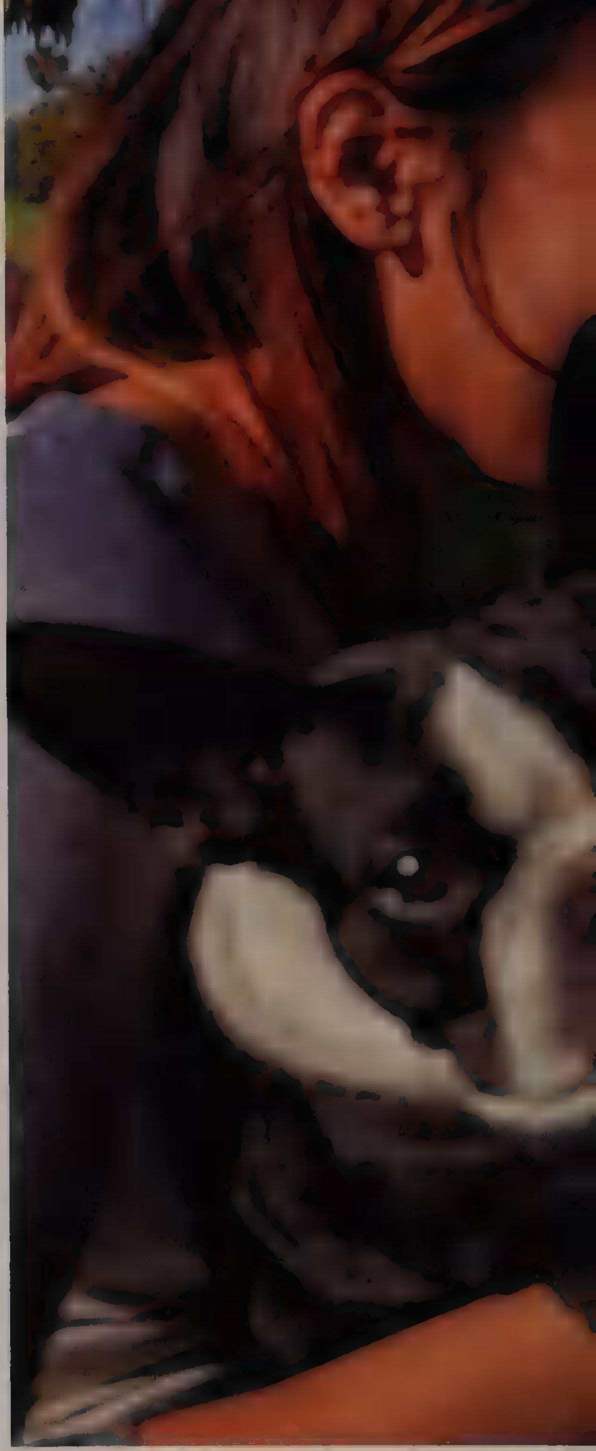
Physical recovery is one thing; mental recovery is a much different matter. Jose's wife, Eliana, whom he married six months after getting injured, remembers some very dark days: Jose, at 24, in a wheelchair in the house, drapes drawn, trying to come to terms with his new life. "I went from being this badass fighter to a young guy in a wheelchair," Jose says. "Your mind doesn't just make an easy switch. I'm not sure it ever will."

Meanwhile, Jose was intent on getting Zenit back. "He was like my worn-out shield," he says. "Every scratch tells a story. And nothing felt right without him." Jose wasn't the only one feeling a nagging sense of incompleteness. Some injured handlers had been able to adopt their dogs after the animals had been discharged. Others had begun asking for their dogs even though the canines remained on active duty.

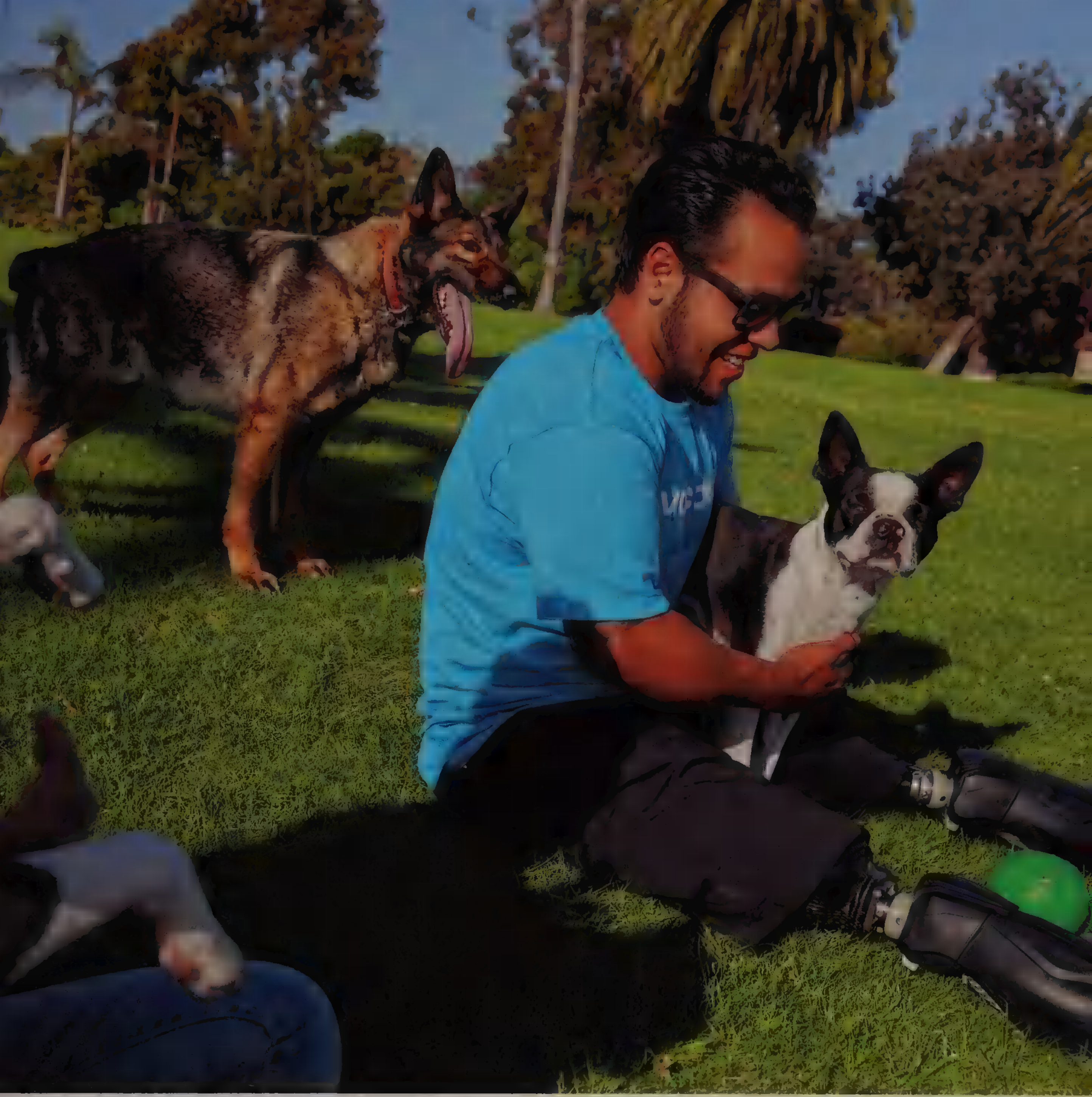
No formal program exists in the military to reunite dogs with their injured handlers, and some of those handlers have found the process inscrutable and frustrating at a time when they needed clarity. For Jose, there were calls and paperwork, excruciating months of waiting. Eventually Zenit was sent to the Marine Corps Air Ground Combat Center in California. More months passed, and finally in June 2012, after the Marine Corps approved the adoption, Jose and his wife road-tripped the three hours to the base. He approached Zenit in his wheelchair, and the dog covered him in slobbery kisses. "I couldn't stop smiling," says Jose. "For days. Actually I'm still smiling. It felt like the beginning to this new life."

IT'S TWILIGHT IN SAN DIEGO. Jose is seated by the pool at his house, drinking a beer, taking a break from his prosthetics, throwing a tennis ball for Zenit. The dog took immediately to eating steak and sleeping on the couch when he first arrived. Jose spoils him as he never could before. The German shepherd's glossy, sable coat flashes in the sun as he chases down each toss with happy zeal, then returns the ball to Jose, who keeps up a patter of "Good boy." It's a long way from war, yet the war seems ever present.

"For a long time I beat myself up over that day," says Jose. "I kept wondering what I could have done differently. I think the IED was offset from where I had Zenit searching or was just buried too deep. They always say that no dog is 100 percent accurate."



Eliana and Jose Armenta relax with their Boston terriers, Oreo and Sassy, and their German shepherd, Zenit. A retired Marine dog handler, Jose lost his legs in an IED blast while on patrol with Zenit. In 2012 he adopted Zenit. "Dogs complete our family," he says, a family soon to include a baby.



For more than a year after that day in the wadi Jose had to learn how to walk on his new legs. He went to rehab several times a week. "He always came in joking and upbeat," says his physical therapist, Dawn Golding. "You could hear him cranking his motivational music when he walked down the hall." Sometimes when he's out for dinner at Buffalo Wild Wings, a kid may see his plastic-and-metal legs and ask if he's a Transformer. "Nah, man," says Jose. "This is what happens when you don't eat your vegetables!" And then he flashes that huge smile.

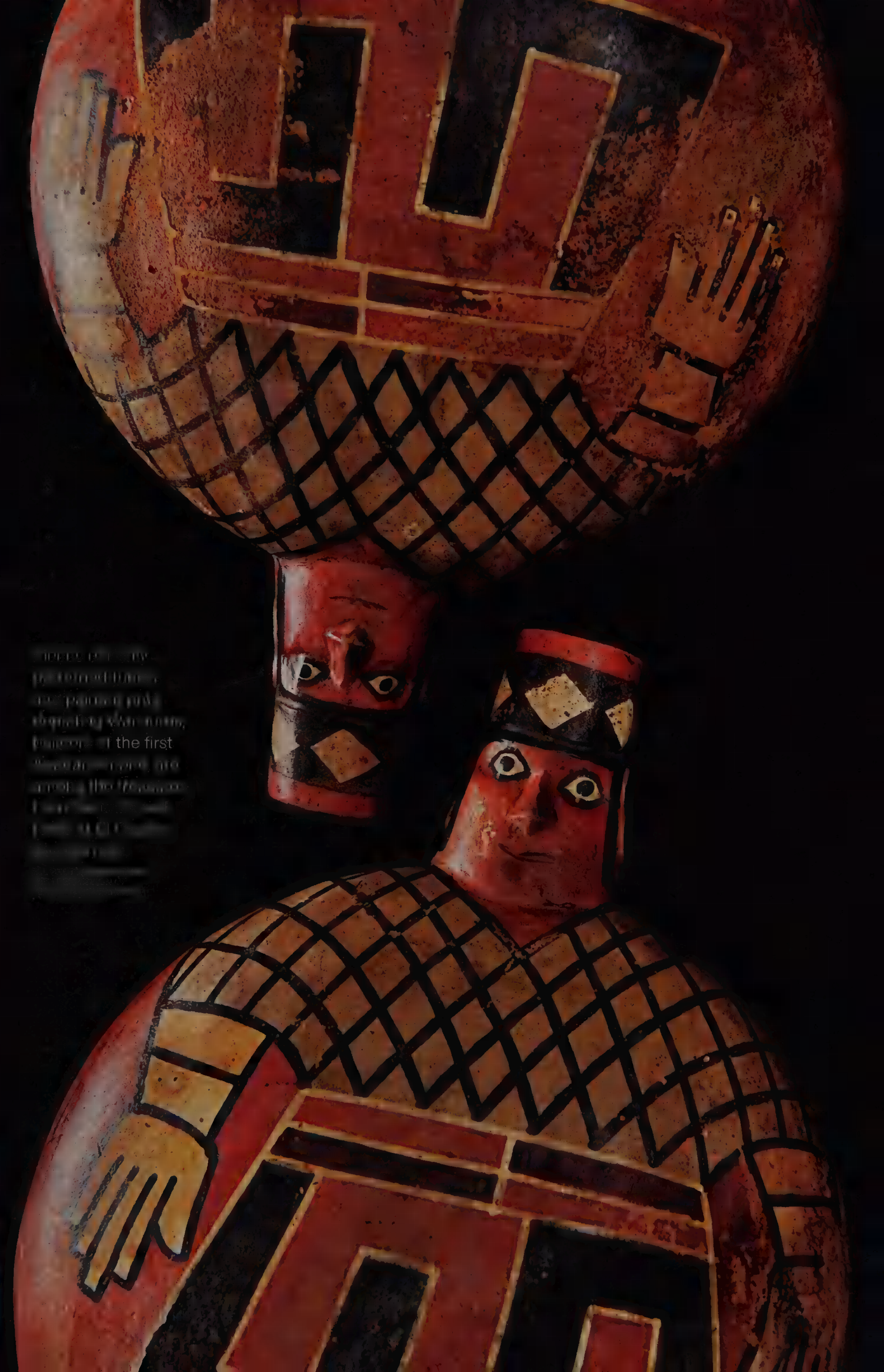
He's learned to sail and ski and has been on outings to Colorado and Alaska. He works as a dispatcher for the military police, on the 4 a.m. to 1 p.m. shift. He comes home to his wife, who is newly pregnant, and they take Zenit to the beach. "He's like my quiet partner," says Jose. "He bridges three worlds: the person I was before Afghanistan, the one I was there, and the one I became after. I joke that when he dies, I'll get him stuffed and put him by the bed. But really I can't imagine it. I don't know what I'll do then."

Jose—brother and husband and soon-to-be father—cocks his arm and releases the ball, which arcs into the darkening sky like some forlorn hope. Before it takes a second bounce, Zenit has it in his mouth, racing to return it to his master. ☐

Untouched

Grave robbers had plundered this ancient Peruvian site for decades. But they missed one royal tomb, hidden for more than 1,000 years.

Remarkably preserved, the hand of an Andean noble still clutches a bit of burial cloth.



[illegible] depicting [illegible], [illegible] the first [illegible] are among the [illegible]

By Heather Pringle

Photographs by Robert Clark

In the late afternoon light along the Peruvian coast, local workmen gather as archaeologists Miłosz Giersz and Roberto Pimentel Nita open a row of small sealed chambers near the entrance of an ancient tomb. Concealed for more than a thousand years under a layer of heavy adobe brick, the mini-chambers hold large ceramic jars, some bearing painted lizards, others displaying grinning human faces. As Giersz pries loose the brick from the final compartment, he grimaces. "It smells awful down here," he splutters. He peers warily into a large undecorated pot. It's full of decayed puparia, traces of flies once drawn to the pot's contents. The archaeologist backs away and stands up, slapping a cloud of 1,200-year-old dust from his pants. In three years of digging at this site, called El Castillo de Huarmey, Giersz has encountered an unexpected ecosystem of death—from

A winged creature adorns a silver and gold ear ornament worn by an elite Wari woman.

traces of insects that once fed on human flesh, to snakes that coiled and died in the bottoms of ceramic pots, to Africanized killer bees that swarmed out of subterranean chambers and attacked workers.

Plenty of people had warned Giersz that excavating in the rubble of El Castillo would be difficult, and almost certainly a waste of time and money. For at least a century looters had tunneled into the slopes of the massive hill, searching for tombs containing ancient skeletons decked out in gold and wrapped in some of the finest woven tapestries ever made. The serpent-shaped hill, located a four-hour drive north of Lima, looked like a cross between the surface of the moon and a landfill site—pitted with holes, littered with ancient human bones, and strewn with modern garbage and rags. The looters liked to toss away their clothing before they returned home for fear of bringing sickness from the dead to their families.

But Giersz, an affable 36-year-old maverick who teaches Andean archaeology at the University of Warsaw, was determined to dig there anyway. Something important had happened at El Castillo 1,200 years ago, Giersz was sure of that. Bits of textiles and broken pottery from Peru's little-known Wari civilization, whose heartland lay far to the south, dotted the slopes. So Giersz and a small research team began imaging what lay underground with a magnetometer and taking aerial photos with a camera on a kite. The results revealed something that generations of grave robbers had missed: the faint outlines of buried walls running along a rocky southern spur. Giersz and a Polish-Peruvian team applied for permission to begin digging.

The faint outline turned out to be a massive maze of towers and high walls spread over the entire southern end of El Castillo. Once painted crimson red, the sprawling complex seemed to be a Wari temple dedicated to ancestor worship. As the team dug down beneath a layer of heavy trapezoidal bricks in the fall of 2012, they discovered something few Andean archaeologists ever expected to find: an unlooted royal tomb. Inside were interred four Wari queens or princesses, at least 54 other highborn individuals, and more than a thousand elite Wari goods, from huge gold ear ornaments to silver bowls and copper-alloy axes, all of the finest workmanship.

"This is one of the most important discoveries in recent years," says Cecilia Pardo Grau, the curator of pre-Columbian art at the Art Museum of Lima. While Giersz and his team continue

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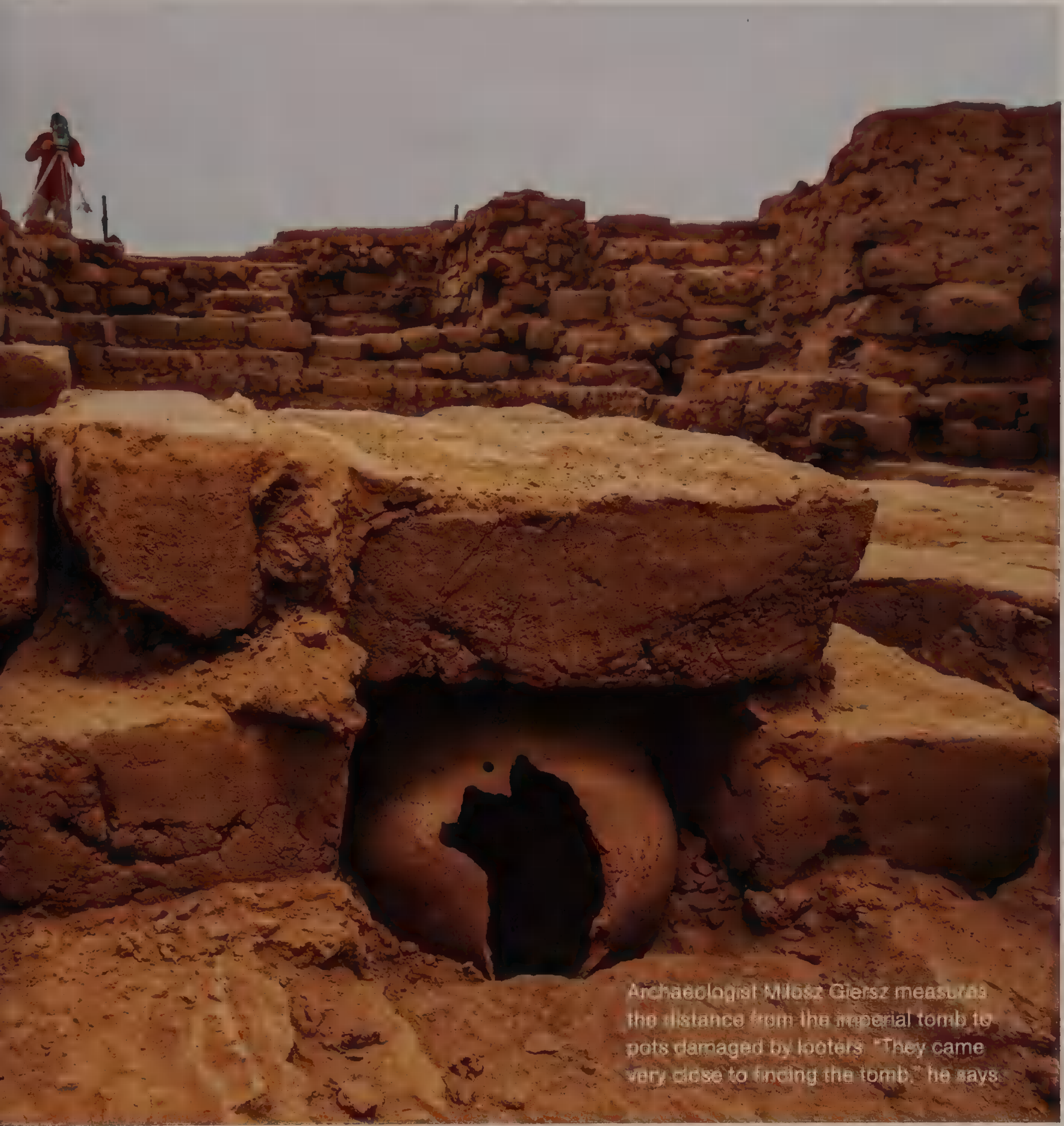
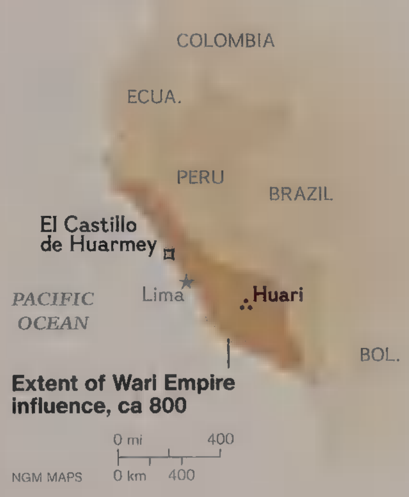
Heather Pringle is the author of The Mummy Congress. *Robert Clark has photographed more than 30 stories for* National Geographic.



Archaeologist Miłosz Giersz measures the distance from the imperial tomb to pots damaged by looters. "They came very close to finding the tomb," he says.

to excavate and explore the site, analysis of the finds is shedding new light on the Wari and their wealthy ruling class.

Emerging from obscurity in Peru's Ayacucho Valley by the seventh century A.D., the Wari rose to glory long before the Inca, in a time of repeated drought and environmental crisis. They became master engineers, constructing aqueducts and complex canal systems to irrigate their terraced fields. Near the modern city of Ayacucho they founded a sprawling capital, known today as Huari. At its zenith Huari boasted a


COLOMBIA
ECUA.
PERU
BRAZIL
El Castillo de Huarmey
PACIFIC OCEAN
Lima
Huari
BOL.
Extent of Wari Empire influence, ca 800
0 mi 400
0 km 400
NGM MAPS

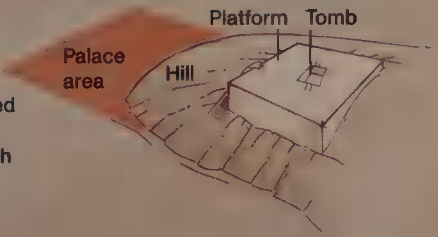
In a maze of chambers, archaeologist Roberto Pimentel Nita crouches to examine a find. The climate at El Castillo is so arid that even delicate threads can survive in the ground for centuries.

Inside a Wari Tomb

After conquering the local lords, the Wari raised a massive imperial tomb at El Castillo. With its crimson-painted walls, this sacred building could be seen for miles around, a constant reminder of the might of the new regime. In the lowest level the Wari interred 58 noblewomen, including 4 queens or princesses. In a chamber above, archaeologists found a throne for displaying the mummy of an important person—possibly the Wari emperor.

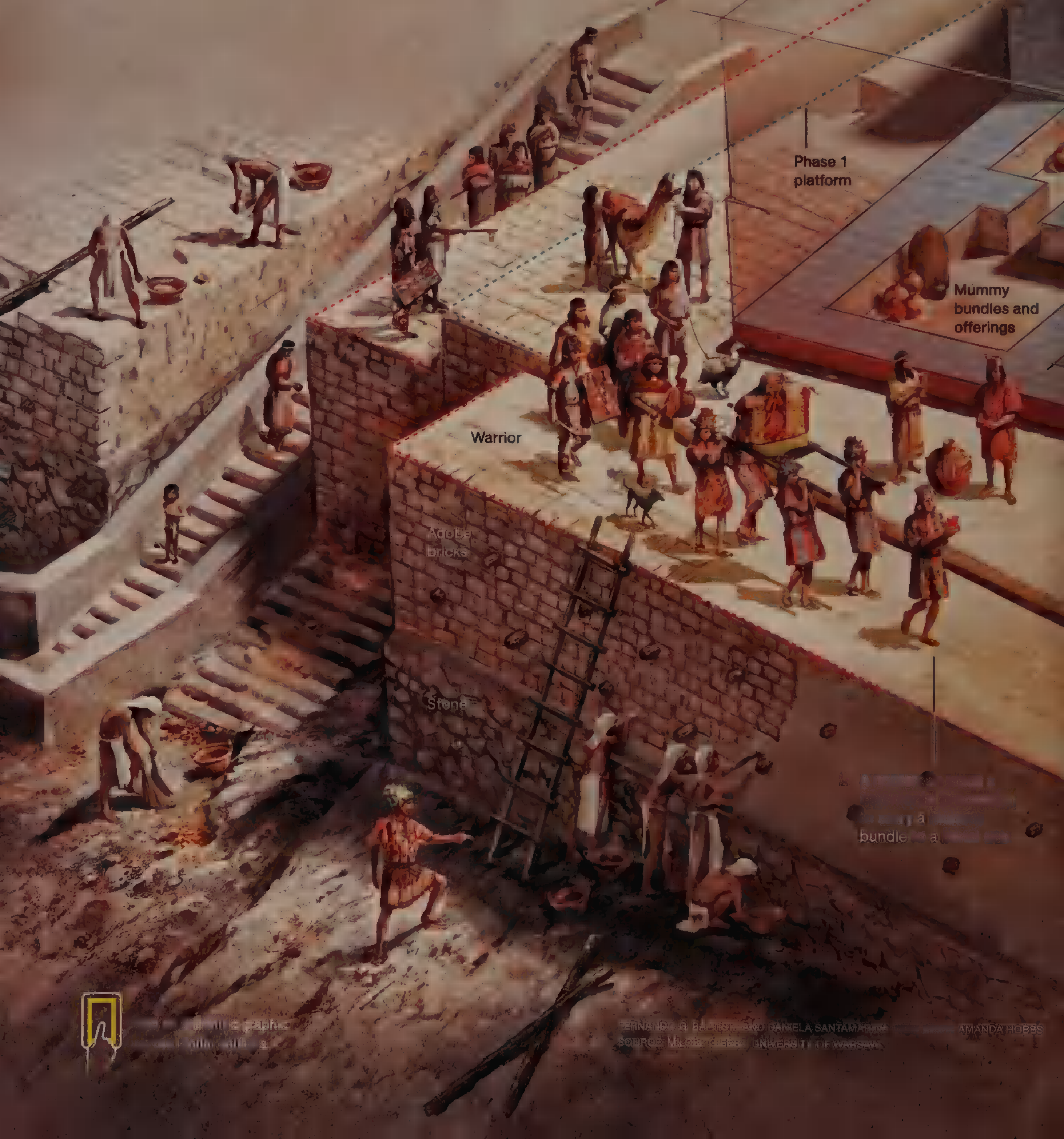
PHASE 1 ▶

Builders carved a burial chamber into the rocky summit. The tomb remained open for several months while it was being filled with mummified bodies.

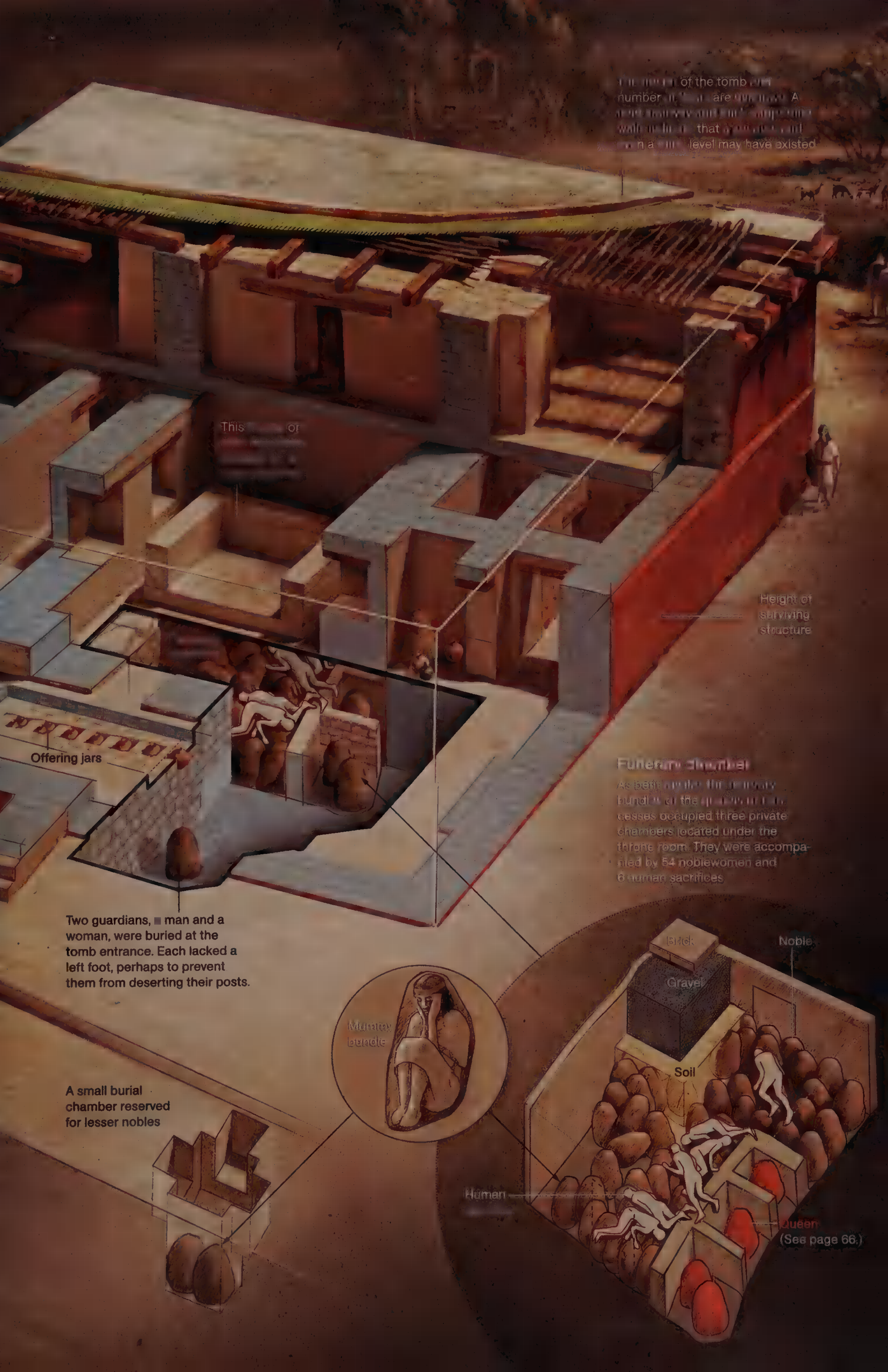

Platform
Tomb
Palace area
Hill

PHASE 2 ▶

Workers expanded the platform, sealed the burial chamber with tons of gravel and a layer of brick, then built rooms above for mummies and offerings.


Phase 2 platform
Phase 1 platform
Mummy bundles and offerings
Warrior
Adobe bricks
Stone
[illegible] a [illegible]
bundle [illegible] a [illegible]

FERNANDO G. BAPTISTA AND DANIELA SANTAMARINA [illegible] AMANDA HOBBS
SOURCE: MILOSZ GIERSZ, UNIVERSITY OF WARSAW



[illegible] of the tomb [illegible] number [illegible] are [illegible]. A [illegible] that [illegible] level may have existed

This [illegible] or [illegible]

Height of
surviving
structure

Offering jars

Funerary chamber

As befit [illegible] the [illegible] bundles of the [illegible]cesses occupied three private chambers located under the throne room. They were accompanied by 54 noblewomen and 6 human sacrifices

Two guardians, [illegible] man and a woman, were buried at the tomb entrance. Each lacked a left foot, perhaps to prevent them from deserting their posts.

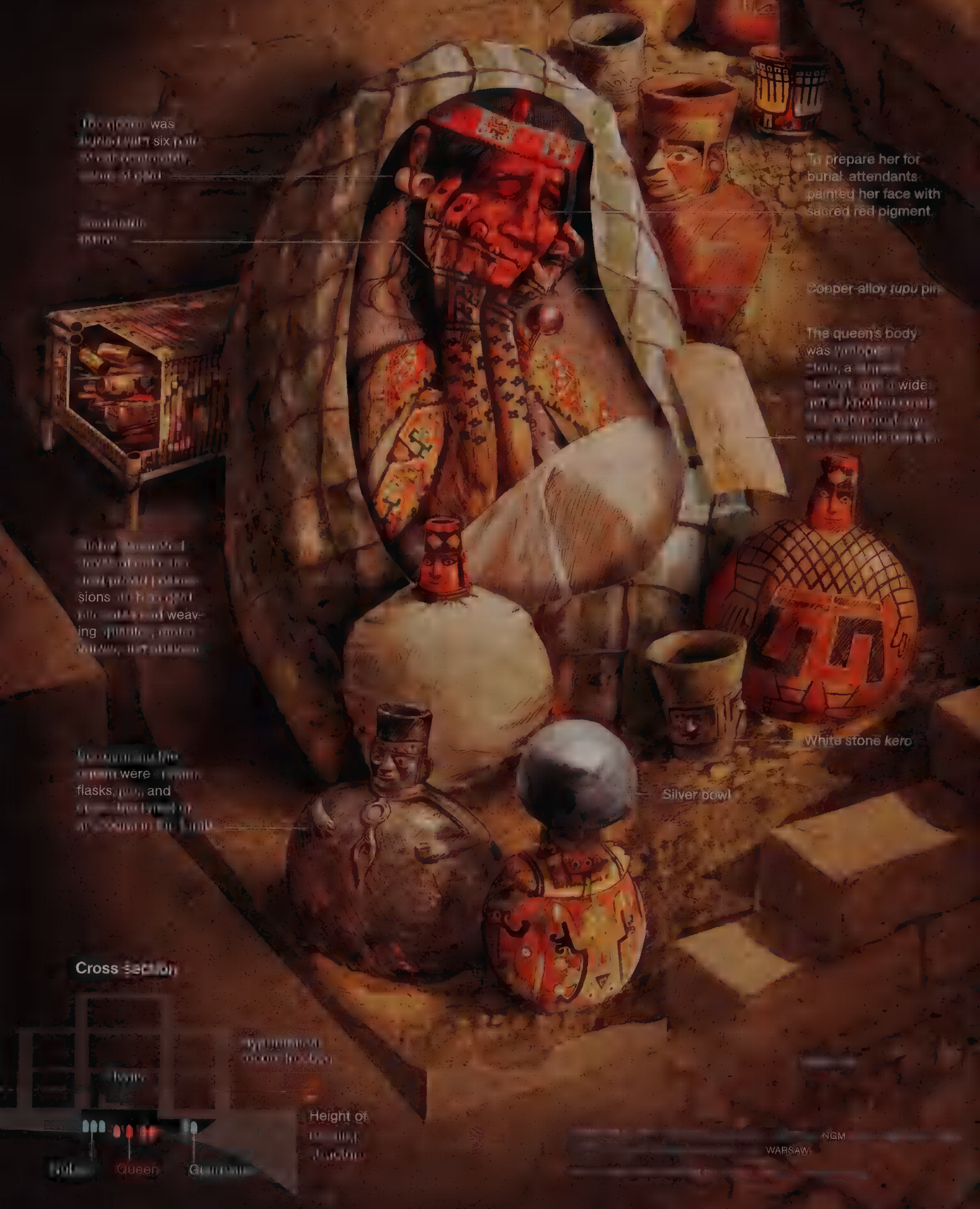
Brick
Noble
Gravel
Mummy bundle
Soil

A small burial chamber reserved for lesser nobles

Human [illegible]
Queen
(See page 66.)

Burial Fit for a Queen

Dying around age 60, this prominent Wari noblewoman went to her grave with wealth and in splendor. Attendants arranged her body in the seated position favored by the Wari, dressed her in a finely woven tunic and shawl, and adorned her with precious jewels. Then they wrapped her in layers of cloth to create a mummy bundle.



The queen was buried with six pairs [illegible]

To prepare her for burial, attendants painted her face with sacred red pigment.

The queen's body was [illegible] cloth, a [illegible] and a wide [illegible] knotted [illegible]

[illegible] sions [illegible] weaving [illegible]

[illegible] were [illegible] flasks, [illegible] and [illegible]

Copper-alloy *tupu* pin
White stone kero
Silver bowl
Cross section
Queen
Height of [illegible]

NGM [illegible]
WARSAW

Skull of El Castillo's great queen

population of as many as 40,000 people—a city larger than Paris at the time, which had no more than 20,000 inhabitants. From this stronghold the Wari lords extended their domain hundreds of miles along the Andes and into the coastal deserts, forging what many archaeologists call the first empire in Andean South America.

Researchers have long puzzled over exactly how the Wari built and governed this vast, unruly realm, whether through conquest or persuasion or some combination of both. Unlike most imperial powers, the Wari had no system of writing and left no recorded narrative history. But the rich finds at El Castillo, a journey of some 500 miles from the Wari capital, are filling in many blanks.

The foreign invaders probably first appeared on this stretch of coast around the end of the eighth century. The region lay along what was then the southern frontier of the wealthy Moche lords, and it seems to have lacked strong local leaders. Just how the invaders launched their offensive is unclear, but an important ceremonial drinking cup discovered in El Castillo's imperial tomb depicts poleax-wielding Wari warriors battling coastal defenders brandishing spear throwers. When the fog of war lifted, the Wari were in firm control. The new lord constructed a palace at the foot of El Castillo, and over time he and his successors began transforming the steep hill above into a towering temple devoted to ancestor worship.

Cloaked in nearly a thousand years of rubble and wind-borne sediment, El Castillo today looks like a huge stepped pyramid, a monument built from the bottom up. But from the beginning Giersz suspected that there was more to El Castillo than met the eye. To tease out the building plan, he invited a team of architecture experts to examine the newly exposed staircases and walls. Their studies revealed something that Giersz had suspected—that Wari engineers began construction along the very top of El Castillo, a natural rock formation, and eventually worked their way downward. They adapted this method from elsewhere, says Krzysztof Makowski, an archaeologist at the Pontifical Catholic University of Peru in Lima and the El Castillo project's scientific adviser. "In the mountains the Wari made agricultural terraces, and they started at the top." As they moved downward, they cut into the slopes to make a tier of platforms.

Along the summit of El Castillo the builders first carved out a subterranean chamber that became the imperial tomb. When it was ready for sealing, laborers poured in more than 30 tons of gravel and capped the entire chamber with a layer of heavy adobe bricks. Then they raised a mausoleum tower above, with crimson walls that could be seen for miles around. The Wari elite left rich offerings in small chambers inside, from the finely woven textiles that ancient Andean peoples valued more highly than gold; to knotted cords known as *khipus*, used for keeping track of imperial goods; to the body parts of the Andean condor, a bird closely associated with the Wari aristocracy. (Indeed, one title of the Wari emperor may well have been Mallku, an Andean word meaning "condor.")

At the center of the tower was a room containing a throne. In later times looters reported to a German archaeologist that they found mummies arrayed in wall niches there. "We are pretty sure this room was used for the veneration of the ancestors," says Giersz. It may even have been used for venerating the emperor's mummy, yet to be discovered by the team.

To rub shoulders in death with members of

Society Grant Archaeologist Miłosz Giersz's work was funded in part by your Society membership.

the royal dynasty, nobles staked out places on the summit for mausoleums of their own. When they exhausted all the available space there, they engineered more, building stepped terraces all the way down the slopes of El Castillo and filling them with funerary towers and graves. So important was El Castillo to the Wari nobles, says Giersz, that they "used every possible local worker." Dried mortar in many of the newly exposed walls bears human handprints, some left by children as young as 11 or 12 years old.

When the construction ended, likely sometime between A.D. 900 and 1000, an immense crimson necropolis loomed over the valley. Though inhabited by the dead, El Castillo conveyed a powerful political message to the living: The Wari invaders were now the rightful rulers. "If you want to take possession of the land," says Makowski, "you have to show that your ancestors are inscribed on the landscape. That's part of Andean logic."

IN A SMALL WALLED CHAMBER along the western slopes of the necropolis, Wiesław Więckowski hunches over a mummified human arm, brushing sand away from its gaunt fingers. For the better part of an hour now the University of Warsaw bioarchaeologist has been clearing this part of the chamber, collecting debris from a Wari funerary bundle and looking for the rest of the body. It's slow, delicate work. As he edges his trowel into the corner of the room, he exposes part of a human femur lodged in a jagged hole in the wall. Więckowski frowns in disappointment. Looters, he explains, probably tried to haul the mummy out from an adjacent room and literally pulled it to pieces. "All we can say is that the mummy was a male person and quite old."

> Social rank mattered as much in death as it did in life.

A specialist in the study of human remains, Więckowski has begun analyzing the skeletons of all the individuals found in and near the imperial tomb. Preservation of human soft tissue in the sealed chamber was poor, Więckowski says, but his studies are starting to fill in key details of the lives and deaths of the highborn women and their guardians.

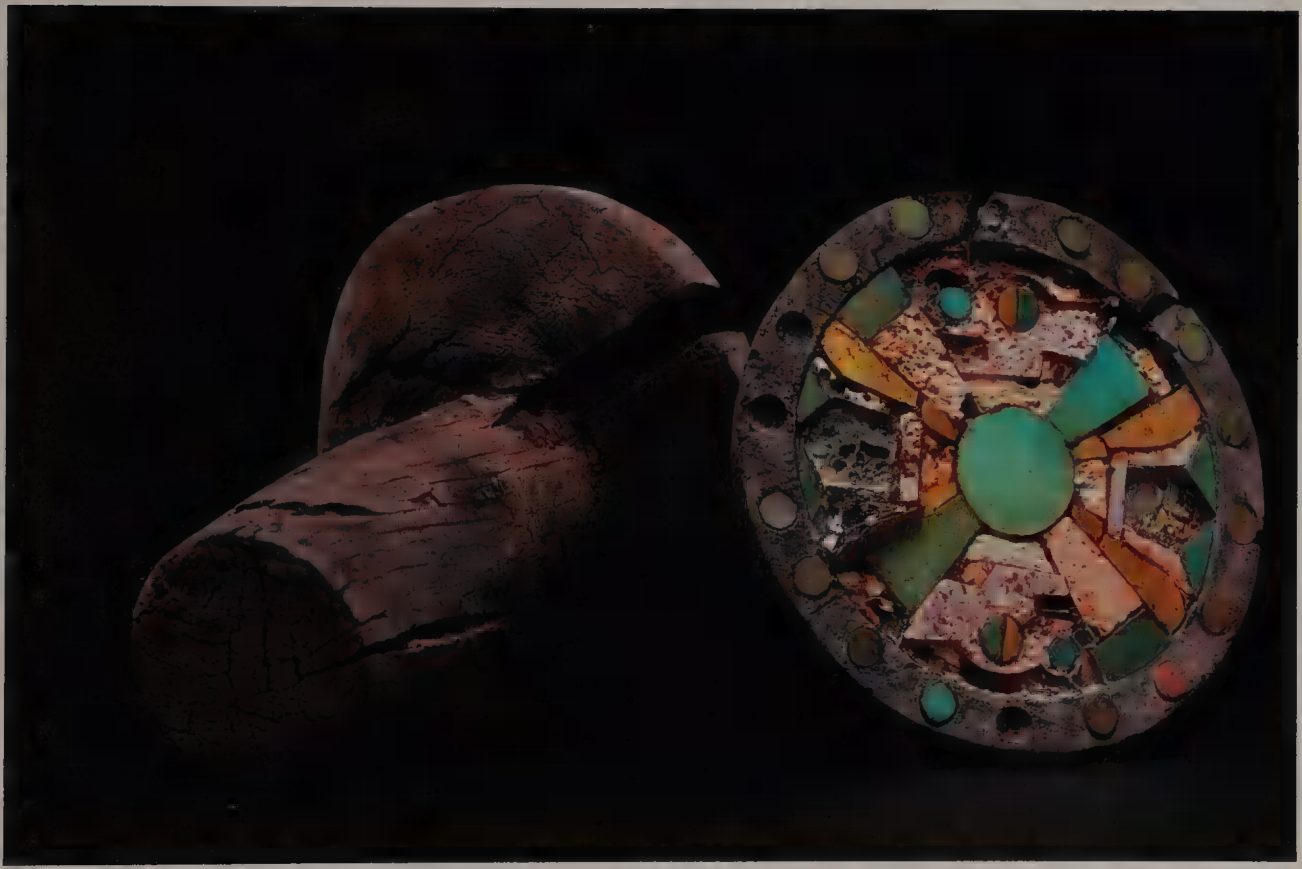
Almost all of those buried inside the chamber were women and girls who had likely died over a period of months, most probably of natural causes. The Wari treated them in death with

In this cross-legged pose, a male guard kept watch over the tomb's treasures for more than a thousand years. By his side were a drinking cup and a gourd.

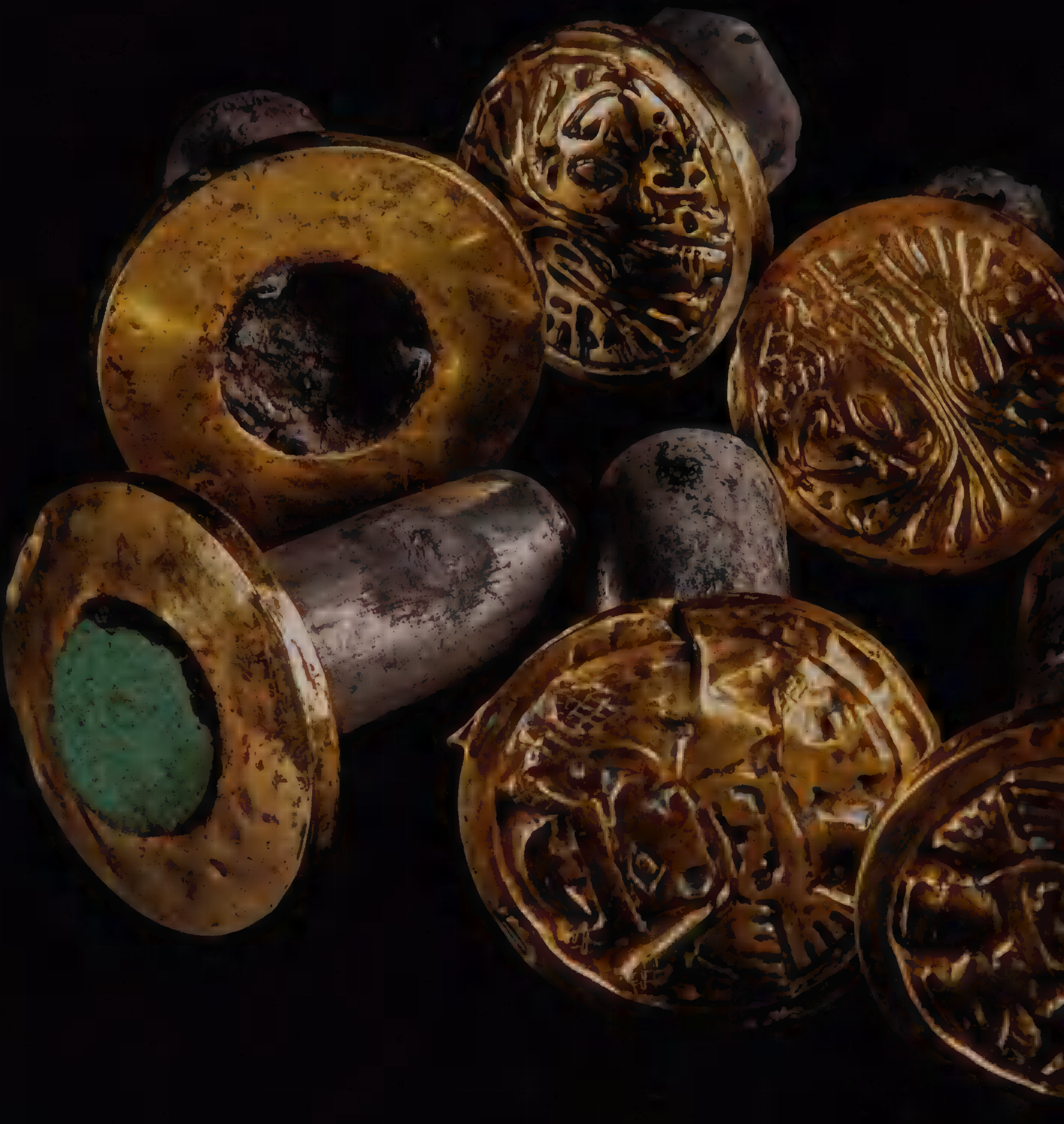
great respect. Attendants dressed them in richly woven tunics and shawls, painted their faces with a sacred red pigment, and adorned them with precious jewelry, from gold ear flares to delicate crystal-beaded necklaces. Then mourners arranged their bodies in the flexed position favored by the Wari and wrapped each in a large cloth to form a funerary bundle.

Their social rank, says Więckowski, mattered as much in death as it did in life. Attendants placed the highest ranked women—perhaps queens or princesses—in three private side chambers in the tomb. The most important, a female of about 60, lay surrounded by rare luxuries, from multiple pairs of ear ornaments to a bronze ceremonial ax and a silver goblet. The archaeologists marveled at her wealth and conspicuous consumption. "This lady, what was she doing?" muses Makowski. "She was weaving with golden instruments, like a true queen."

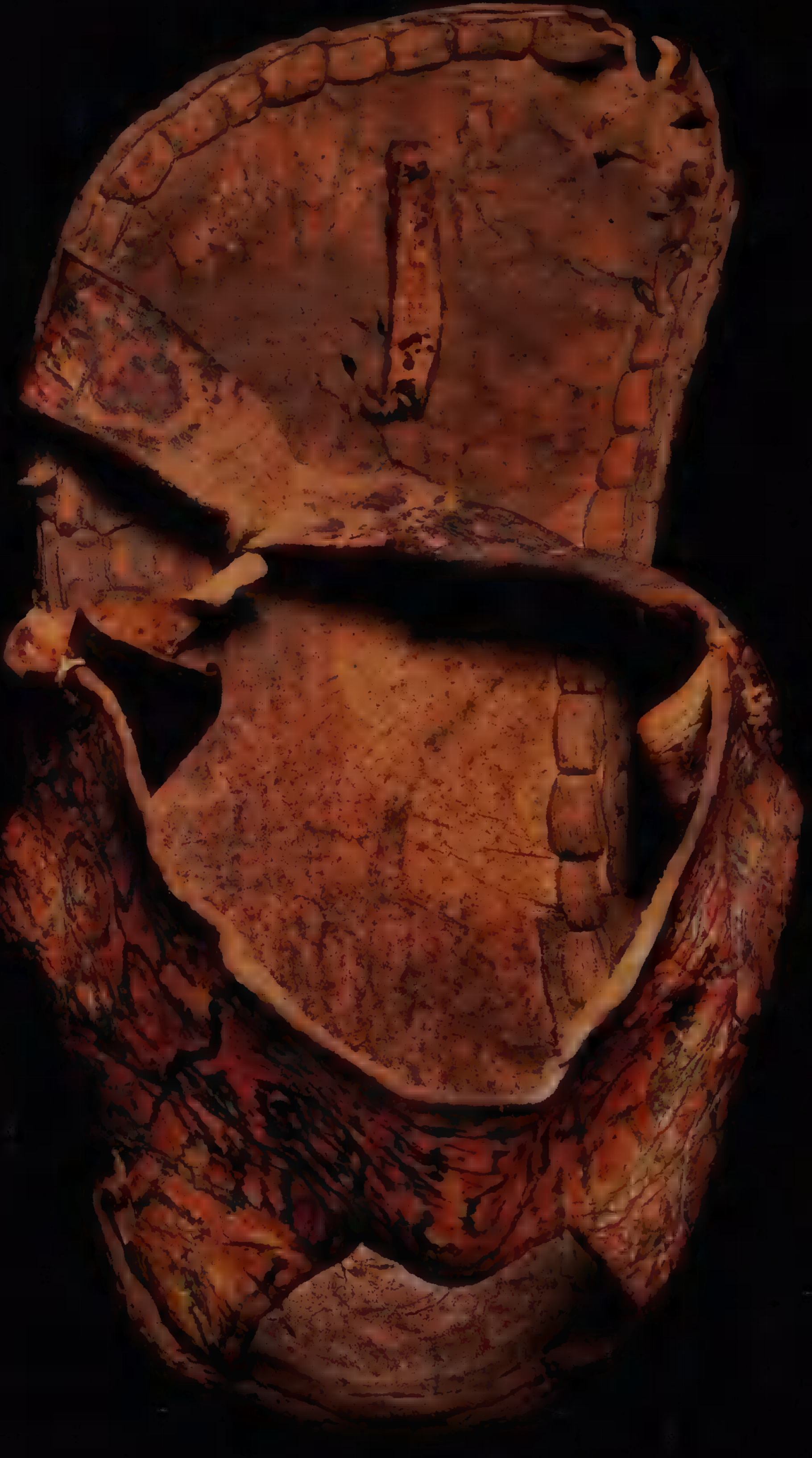
Beyond, in a large common area, attendants arranged the lesser noblewomen along the walls. Beside each, with few exceptions, they laid a container roughly the *(Continued on page 76)*



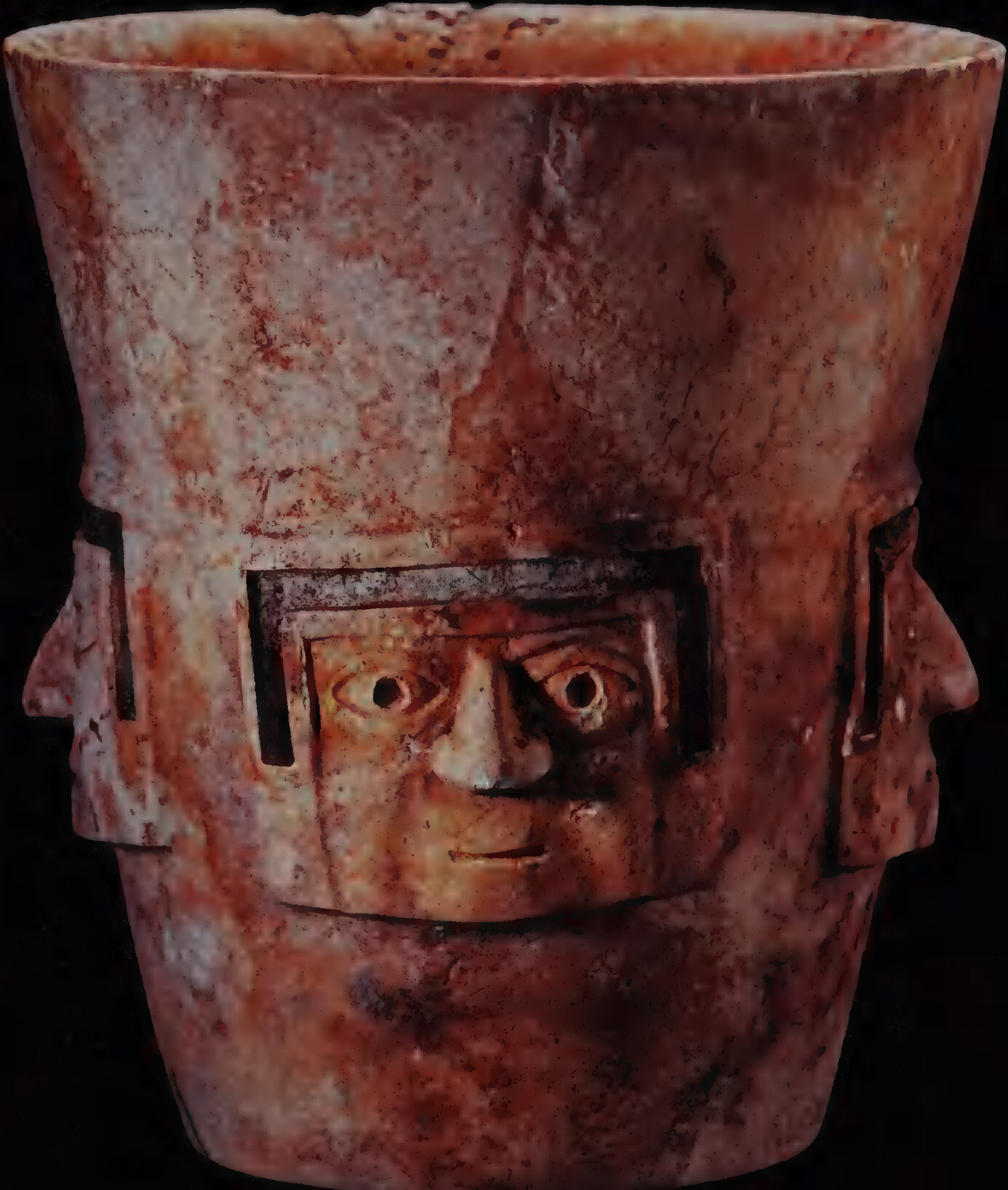
The painted figure on a ceramic flask (left) depicts a Wari lord sitting atop a balsa raft—a clue, perhaps, that the Wari invaded the territory by sea. The unlooted tomb at El Castillo has yielded more than a thousand objects tailor-made for Wari nobles, including wooden ear ornaments inlaid with gold, shell, and precious stones (above) and two jars that held offerings to revered ancestors.



High-ranking Wari women wore ear ornaments, some as big as doorknobs. The discovery of gold and silver artifacts brought sleepless nights for the archaeologists, who feared being robbed.



The Wan elite dressed well, even down to fine footwear of brightly painted leather. They drank well too. For a queen, an artisan carved this drinking cup from an alabaster-like Arabian stone.



In a modern cemetery near El Castillo a looter displays a plundered textile for prospective customers. The tomb at El Castillo is now closely guarded.

size and shape of a shoe box. Made of cut canes, it stored all the weaving tools needed to create high-quality cloth. Wari women were consummate weavers, producing tapestry-like cloth with yarn counts higher than those of the famous Flemish and Dutch weavers of the 16th century. The noblewomen buried at El Castillo were clearly dedicated to this art, creating textiles of the finest quality for the Wari elite.

When the chamber was ready for sealing, attendants brought the last offerings up the slopes of El Castillo: human sacrifices. There were six individuals in all, three children—including what might be a nine-year-old girl—and three young adults. It's possible, says Więckowski, the victims were the offspring of the conquered nobility. "If you are the ruler and want people to prove their loyalty to the lineage, you take their children," he says. When the killings were done, attendants threw the corpses into the tomb. Then they closed the chamber, placing the wrapped corpses of a young adult male in his prime and of an older woman at the entrance as guards. Each body had lost a left foot, perhaps ensuring

that they couldn't desert their posts.

Więckowski is awaiting the results of DNA analyses and isotopic tests to learn more about the females in the tomb and where they might have come from. But for Giersz the evidence is all beginning to add up to a detailed picture of the Wari invasion of the north coast. "The fact that they built an important temple here, on a prominent piece of land along the former borders of the Moche, strongly suggests that the Wari conquered the region and intended to stay."

In a quiet back room at the Art Museum of Lima, El Castillo's archaeologists beam as they examine some of the newly cleaned finds. For weeks now conservators have been stripping away the thick, black patina that coated many of the metal artifacts, revealing glimmering designs. Cushioned in tissue paper are three gold ear ornaments, each roughly the size of a doorknob and bearing the image of a winged deity or mythical being. Team member Patrycja Prządka-Giersz, a University of Warsaw archaeologist who is married to Giersz, looks them over in delight. These adornments, she says, "are all different, and we can only see them after conservation."

Peering inside a large cardboard box on the table, Giersz finds one of the team's prize discoveries: a ceramic pilgrim's flask. Richly painted and decorated, the flask depicts a sumptuously dressed Wari lord voyaging by balsa raft across coastal waters teeming with whales and other sea creatures. Found among the cherished grave goods of a dead queen at El Castillo, the 1,200-year-old flask seems to portray an event—partly mythical, partly real—in the history of the north coast, the arrival of an important Wari lord, possibly even the Wari emperor himself.

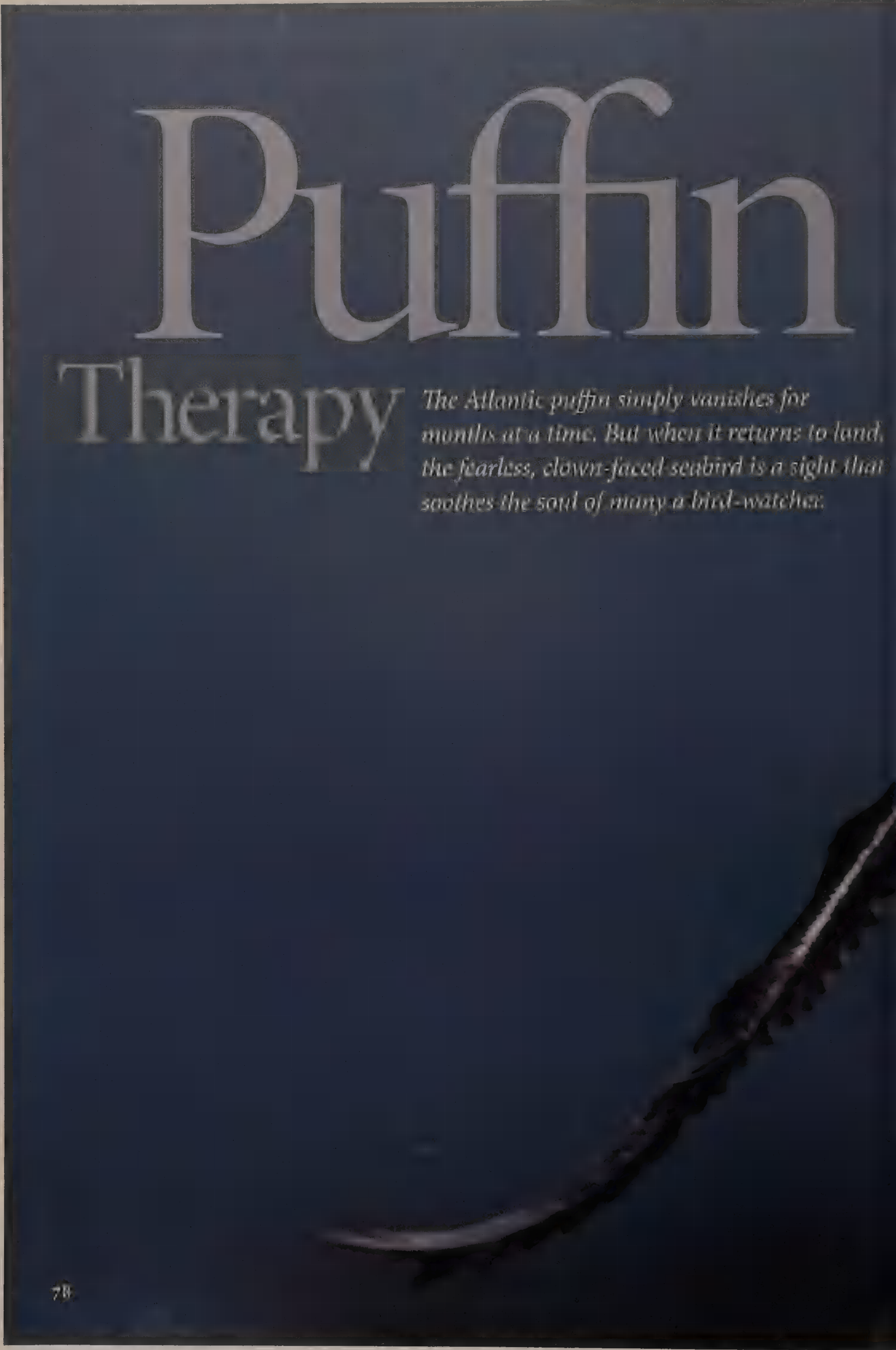
> **The tomb of a great Wari lord may lie somewhere in the maze of chambers.**

"And so we are starting to make a story of the Wari emperor who takes to the sea in a raft," says Makowski with a smile, "an emperor who dies on the Huarmey coast accompanied by his wives."

For now it is only a story, an educated archaeological guess. But Giersz, the maverick who saw the buried outlines of walls where others saw only looters' rubble, still thinks that the tomb of a great Wari lord may lie somewhere in the maze of walls and subterranean chambers. And if the looters haven't beaten him to the punch, he intends to find it. ☐

Puffin Therapy

The Atlantic puffin simply vanishes for months at a time. But when it returns to land, the fearless, clown-faced seabird is a sight that soothes the soul of many a bird-watcher.



Swooping in for a landing, an Atlantic puffin brings a meal for its chick on Scotland's Treshnish Isles. Puffin parents make up to eight food runs a day; each bird can grip 20 or more fish in its beak.

A puffin eyes its realm at the Hermaness Reserve in the Shetland Islands. Puffins burrow near cliff edges for quick access to the sea, watching out for gulls and other seabirds that steal their food.

It's called billing: the rubbing and clacking of beaks when puffins court. On Skomer Island in Wales a pair displays the grooved orange beak and bright eye ring of breeding puffins.

Photographs by Danny Green

Here they come, wings beating like a manic pulse, bodies a blur of black and white, a flash of orange from beaks cartoonishly large. Cliff tops, empty and dark for months, turn to commotion near the beginning of April with the arrival of antic, adorable-looking Atlantic puffins.

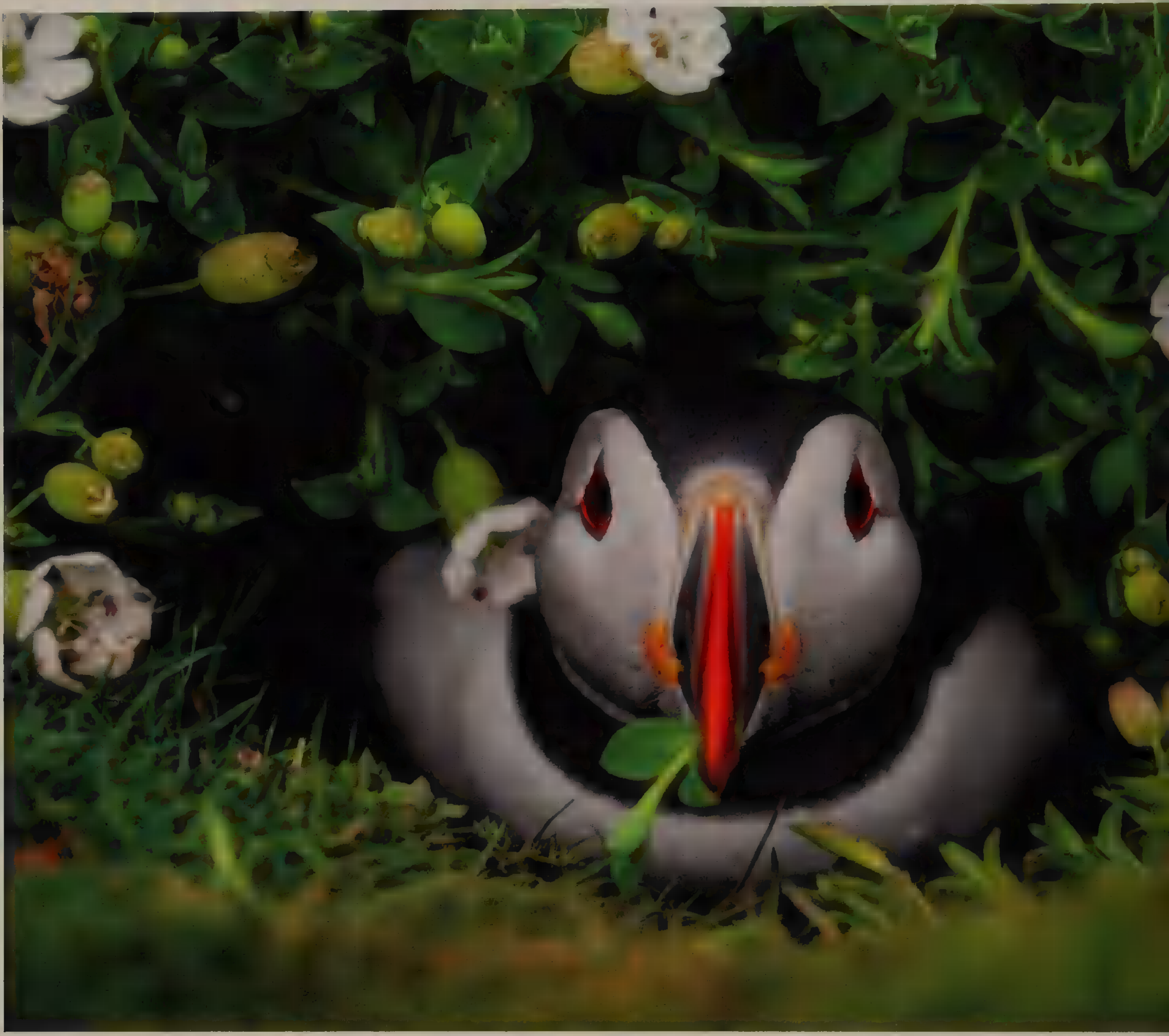
Smallest of the four puffin species, they have come en masse to breed on Britain's rumpled islands and coasts, the more remote, unpeopled, and predator free, the better. No one is certain precisely how and where *Fratercula arctica* ("little friar of the Arctic," so named for its monkish, dark-colored hood) spends the rest of the year. They are somewhere in the vast northern seas, solitary, almost never seen, as they fly, feed, and float.

Ah, but spring. It's like carnival time for puffins. Breeding is the only excuse for these seabirds to go on land. They become intensely social, courting, mating, tussling. Assemblages vary from a few hundred pairs in Maine to tens of thousands in Iceland. The British Isles, scene of Danny Green's photographs, attract about 10 percent of an estimated 20 million Atlantic puffins (nobody really knows), with Iceland claiming almost half.

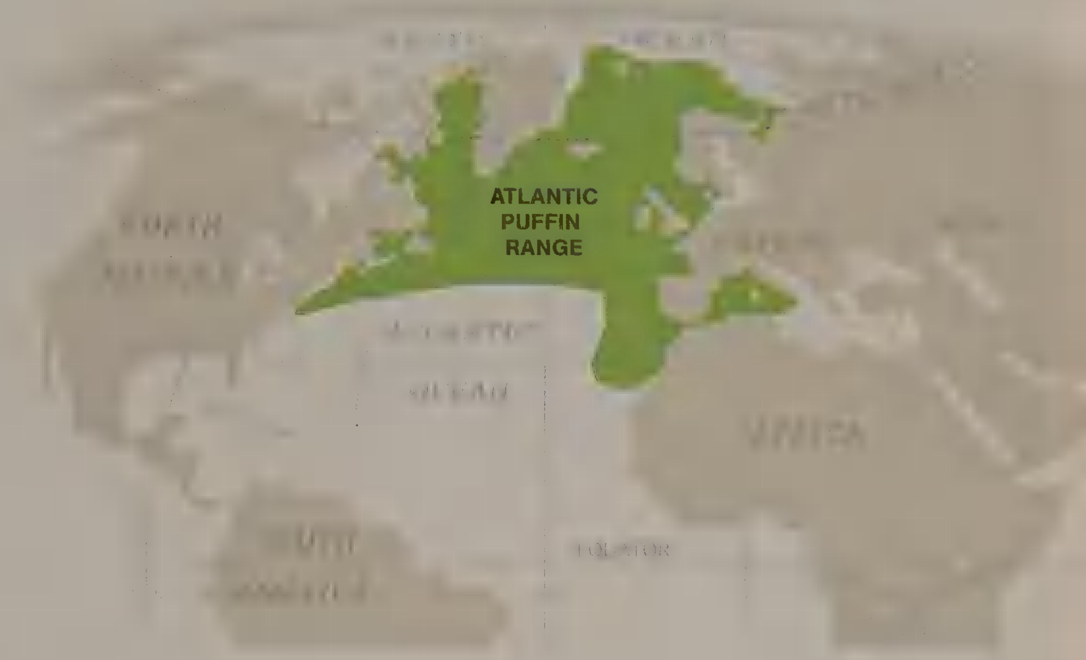
For the breeding season puffins change their costume. Their beaks grow thicker and brighter, white feathers replace black ones, and eye ornaments appear, the face now like a Kabuki actor's. After pairing up, often with the same partner as in previous years, puffins use that gaudy beak and their webbed feet to dig a burrow in the soft earth. (In some locations the birds nest among rocks and boulders.) The female lays one egg, which the male and female take turns incubating under a wing. They share feeding duties too; the female makes the most trips, racing back from the water with beakfuls of fish, intent on avoiding gulls, skuas, and other aerial pirates.

Unlike penguin colonies, often cramped, loud, and peckish, a puffin gathering is mostly mellow and quiet. In the British Isles, where puffins have not been hunted for a century (puffin hunting remains legal

Loading up on dried stems and fresh leaves, a puffin goes about its spring chore of picking up material to line its burrow. "They collect with a vengeance," says expert Mike Harris. Items especially prized include feathers, bits of string and paper, and seaweed.



Peeking from its burrow, a puffin snips off a bloom to dress up its temporary home on Skomer Island, where 6,000 pairs breed. Burrows usually extend several feet or more to keep egg and chick safe. Chicks are rarely seen, staying hidden for six weeks or so until flying off one night.



LAUREN E. JAMES, NGM STAFF. SOURCES: BIRDLIFE INTERNATIONAL AND NATURESERVE; MIKE HARRIS, CENTRE FOR ECOLOGY & HYDROLOGY, EDINBURGH

in Iceland), the seven-inch-tall birds can be remarkably tame, tolerating human visitors. Iain Morrison, who for 42 years has taken birders to the Treshnish Isles in Scotland, says he can't help noticing that "communing with puffins makes people happy. I call it puffin therapy."

Concern, however, is starting to shadow the faces of those who study puffins. In the past decade most populations have been declining. Certain colonies in Iceland, Norway, and likely Scotland's Shetland Islands have in some years produced almost no young. The favored small fish, like sand eels, sprat, and herring, are becoming scarcer and even smaller. Warming water temperatures appear to be upsetting the food chain.

Mike Harris, who studies the colony on Scotland's Isle of May, says bluntly, "Puffins are having problems raising chicks." Reaching an average of 30 years, puffins, like all long-lived birds, "can afford to skip the breeding cycle for a few years until conditions improve," he says. "But the current long run of low success is going to affect the total population."

In the meantime there's cause for celebration at a few sites, such as Skomer Island in Wales. For reasons not totally understood, puffin numbers here are increasing, the burrows full. Come August, the colony's chicks reliably depart, waddling down the steep slopes to swim and fly away, facing many cold months on their own. They know their way back. And if you're a puffin, how can you pass up a crowd in springtime? —*Tom O'Neill*

Dueling puffins flare their wings and part their beaks in a muddy tussle on Skomer Island. Most puffin fights start over competing claims to a burrow. A bite to the neck usually settles the issue.

From April to August puffins take over fog-swept cliffs at Hermaness Reserve. Many return to the same partner and burrow. What exactly a puffin does in winter remains a mystery.

The Future of FOOD natgeofood.com

By 2050 we'll need to feed two billion more people. This special eight-month series explores how we can do that—without overwhelming the planet.

Can the "blue revolution" solve the world's food puzzle?

The world now produces more farmed fish than beef—and that's just the beginning.

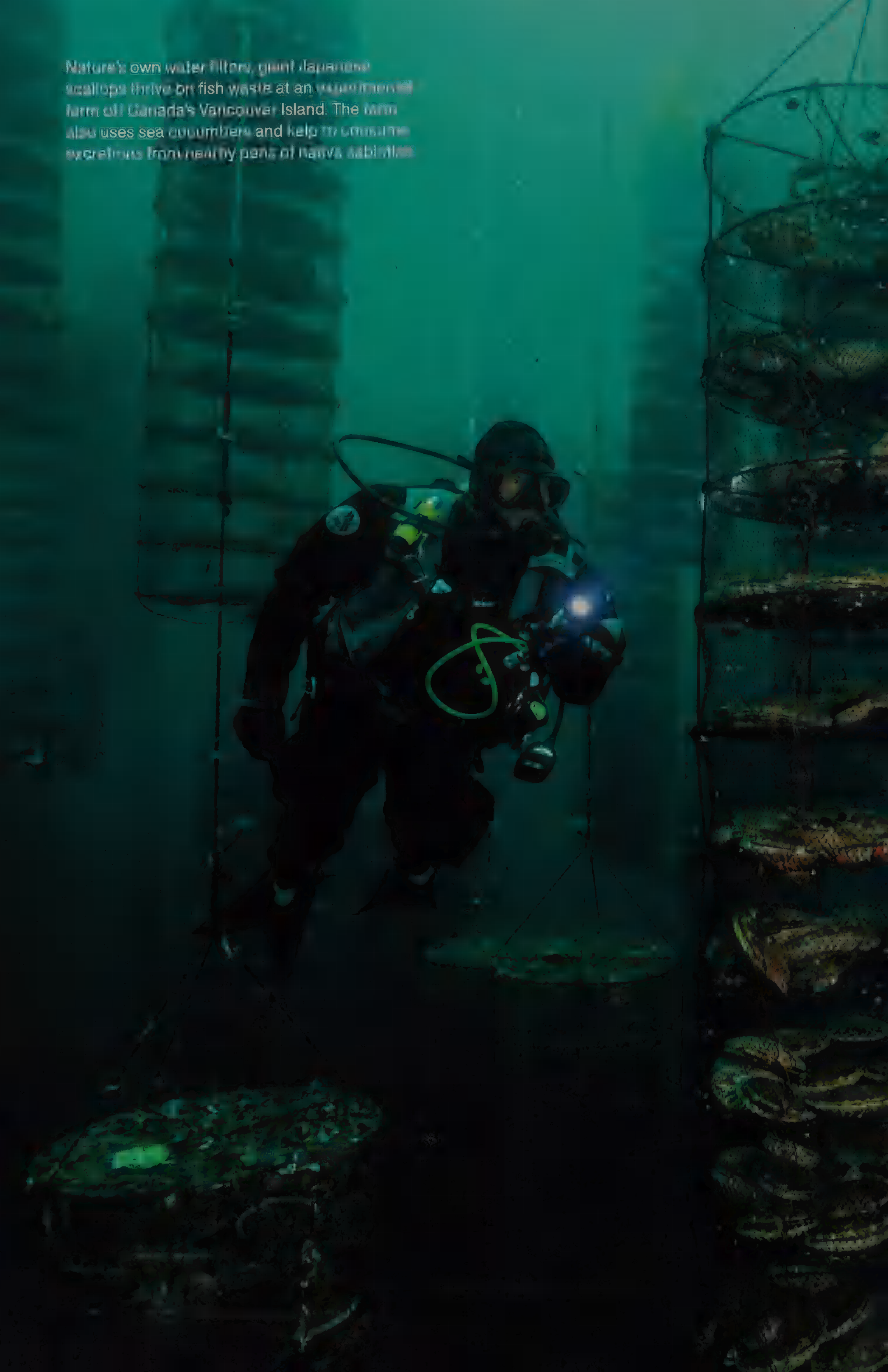
How to Farm a Better Fish

By *Joel K. Bourne, Jr.*

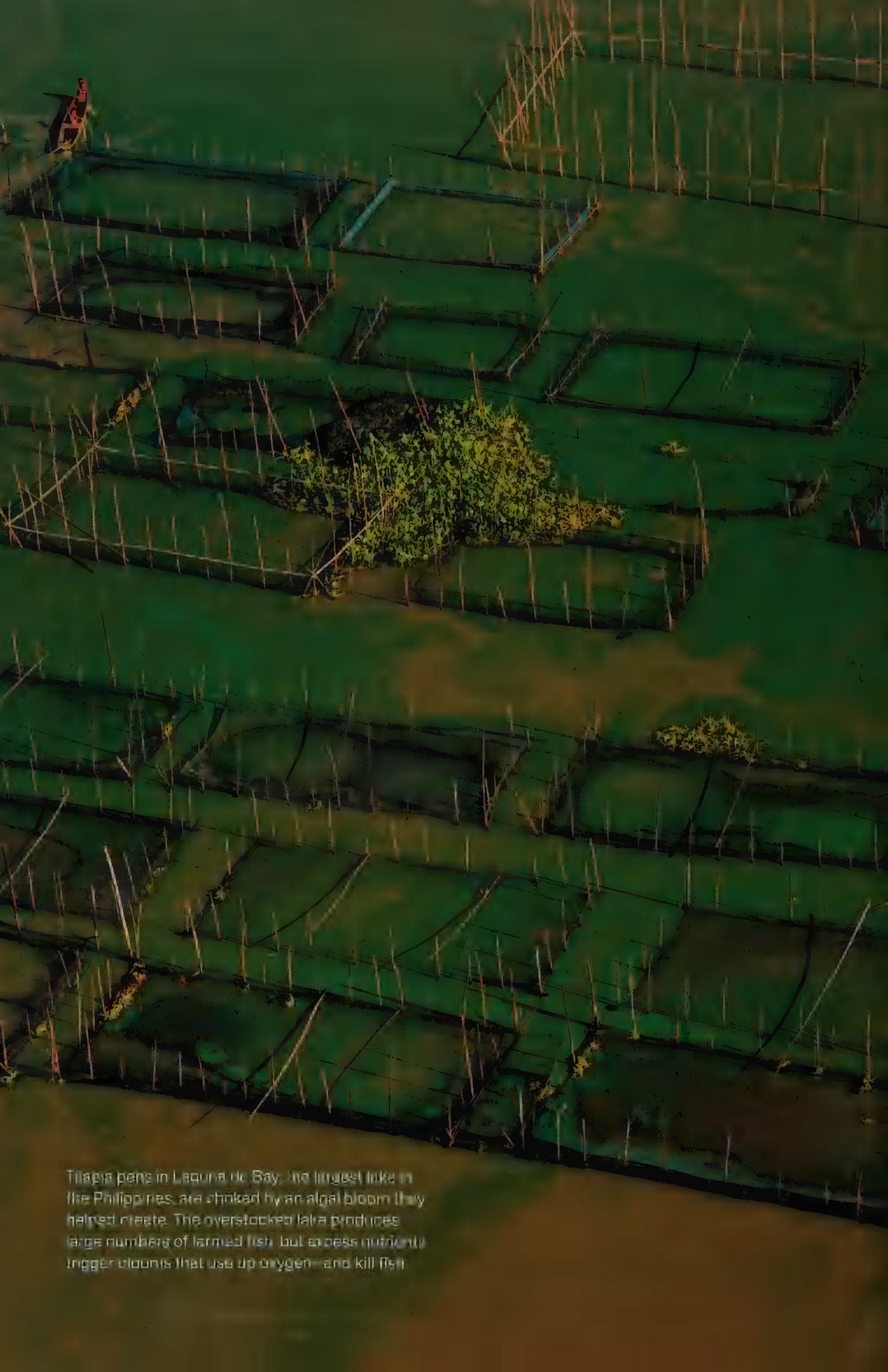
Photographs by *Brian Skerry*

Solaiman Sheik shows off the harvest from his father's small pond near Khulna, Bangladesh: freshwater prawns, a profitable export. The family also raises fish in the pond and, in the dry season, rice fertilized by fish waste—a polyculture that has tripled output with little environmental downside.

JIM RICHARDSON



Nature's own water filters, giant Japanese scallops thrive on fish waste at an experimental farm off Canada's Vancouver Island. The farm also uses sea cucumbers and kelp to consume excretions from nearby pens of native sablefish.



Tilapia pens in Laguna de Bay, the largest lake in the Philippines, are choked by an algal bloom they helped create. The overstocked lake produces large numbers of farmed fish, but excess nutrients trigger blooms that use up oxygen—and kill fish.

In a dark, dank warehouse in the Blue Ridge foothills of Virginia, Bill Martin picks up a bucket of brown pellets and slings them into a long concrete tank. Fat, white tilapia the size of dinner plates boil to the surface.

Martin, president of Blue Ridge Aquaculture, one of the world's largest indoor fish farms, smiles at the feeding frenzy.

"This is St. Peter's fish, the fish Jesus fed the multitudes," he says, his raspy voice resonating like a preacher's. Unlike Jesus, however, Martin does not give his fish away. Each day he sells 12,000 pounds of live tilapia to Asian markets from Washington, D.C., to Toronto, and he's planning another farm on the West Coast. "My model is the poultry industry," he says. "The difference is, our fish are perfectly happy."

"How do you know they're happy?" I ask, noting that the mat of tilapia in the tank looks thick enough for St. Peter to walk on.

"Generally they show they're not happy by dying," Martin says. "I haven't lost a tank of fish yet."

An industrial park in Appalachia may seem an odd place to grow a few million natives of the Nile. But industrial-scale fish farms are popping up everywhere these days. Aquaculture has expanded about 14-fold since 1980. In 2012 its global output, from silvery salmon to homely sea cucumbers only a Chinese cook could love, reached more than 70 million tons—exceeding beef production clearly for the first time and amounting to nearly half of all fish and shellfish consumed on Earth. Population growth, income growth, and seafood's heart-healthy reputation are expected to drive up demand by 35 percent or more in just the next 20 years. With the global catch of wild fish stagnant, experts say virtually all of that new seafood will have to be farmed.

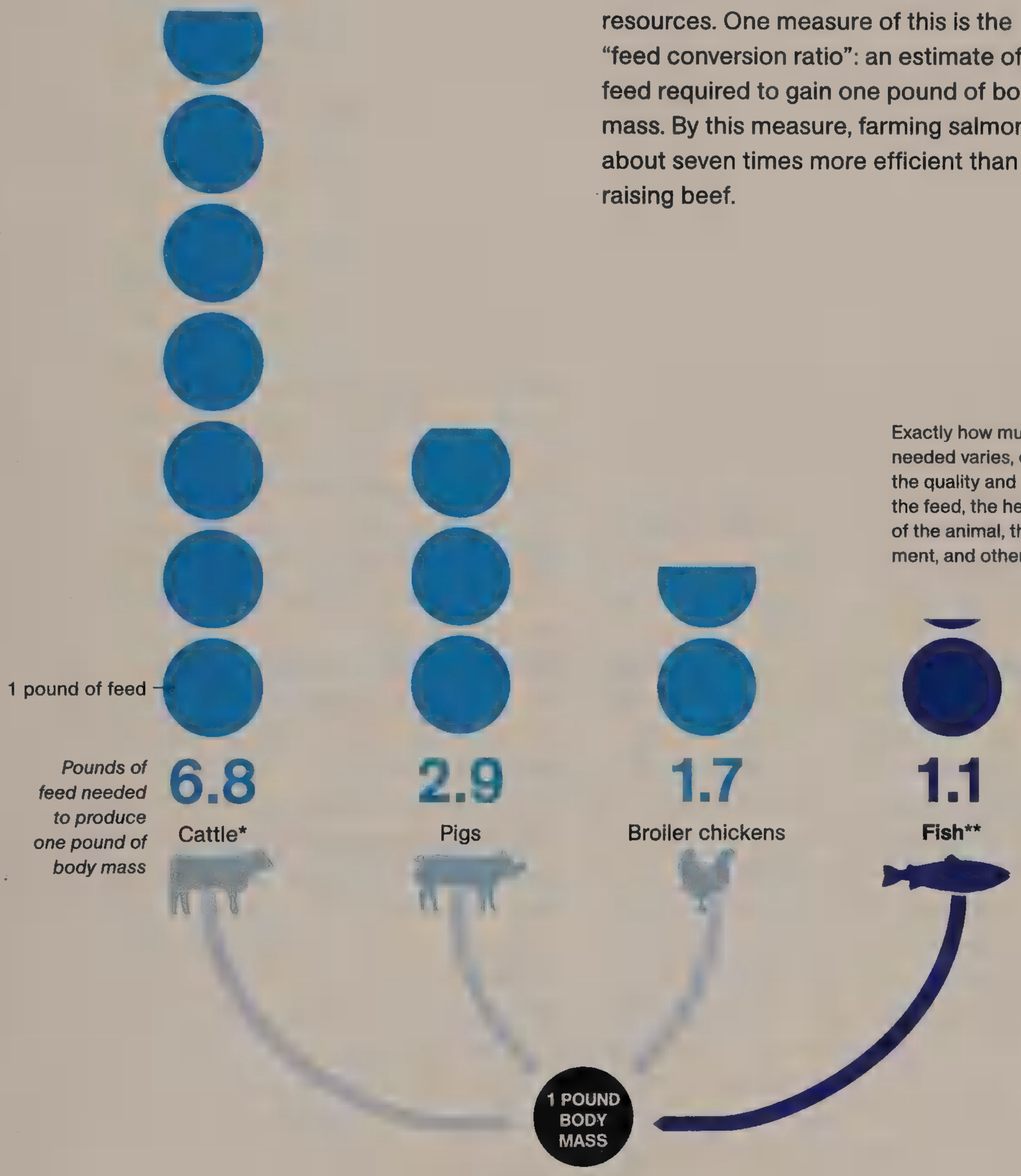
"There is no way we are going to get all of the protein we need out of wild fish," says Rosamond Naylor, a food-policy expert at Stanford University who has researched aquaculture systems. "But people are very wary that we're going to create another feedlot industry in the ocean. So they want it to be right from the start."

There are good reasons to be wary.

THE NEW "BLUE REVOLUTION," which has delivered cheap, vacuum-packed shrimp, salmon, and tilapia to grocery freezers, has brought with it many of the warts of agriculture on land: habitat destruction, water pollution, and food-safety scares. During the 1980s vast swaths of tropical mangroves were bulldozed to build farms that now produce a sizable portion of the world's shrimp. Aquacultural pollution—a putrid cocktail of nitrogen, phosphorus, and dead fish—is now a widespread hazard in Asia, where 90 percent of farmed fish are located. To keep fish alive in densely stocked pens, some Asian farmers resort to antibiotics and pesticides that are banned for use in the United States, Europe, and Japan. The U.S. now imports 90 percent of its seafood—around 2 percent of which is inspected by the Food and Drug Administration. In 2006

Pounds for Pound

Different sources of animal protein in our diet place different demands on natural resources. One measure of this is the "feed conversion ratio": an estimate of the feed required to gain one pound of body mass. By this measure, farming salmon is about seven times more efficient than raising beef.



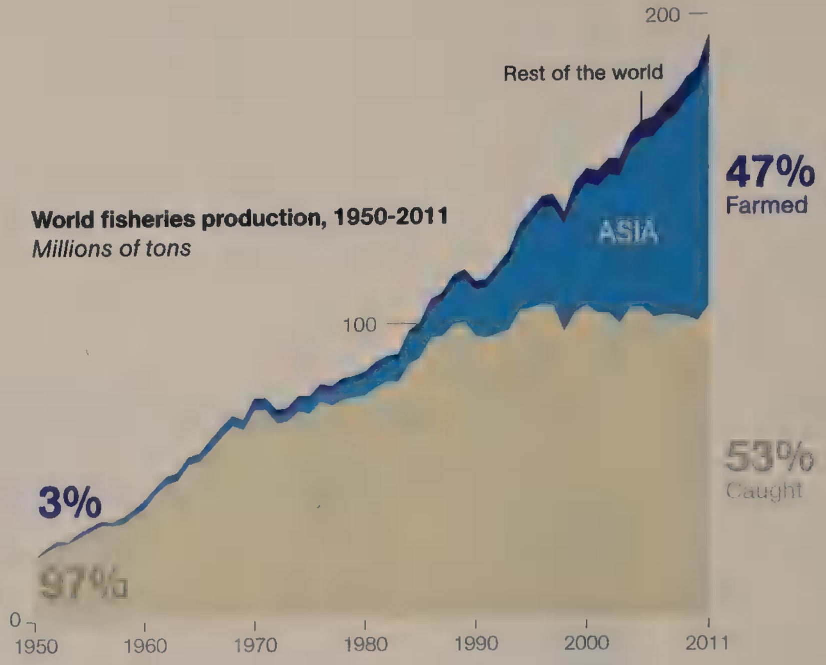
Exactly how much feed is needed varies, depending on the quality and makeup of the feed, the health and age of the animal, the environment, and other factors.

*Hereford ratio; ratios for other cattle breeds vary
**Salmon ratio; ratios for other fish slightly higher

GRAPHIC AND CHART BY VIRGINIA W. MASON AND JASON TREAT, NGM STAFF; SHELLEY SPERRY
SOURCES: MALCOLM BEVERIDGE, WORLDFISH; RODNEY HILL, UNIVERSITY OF IDAHO; ROBERT SWICK, UNIVERSITY OF NEW ENGLAND, AUSTRALIA; U.K. AGRICULTURE AND HORTICULTURE DEVELOPMENT BOARD

Farming Expands as the Wild Catch Stalls

With demand rising and many marine fish stocks already overfished, nearly half of all seafood now comes from aquaculture, which has grown at a double-digit clip for decades. Most of the growth is in Asia, home to 90 percent of fish farms.



and 2007 the FDA discovered numerous banned substances, including known or suspected carcinogens, in aquaculture shipments from Asia.

Nor have fish farms in other parts of the globe been free of problems. The modern salmon industry, which over the past three decades has plunked densely packed net pens full of Atlantic salmon into pristine fjords from Norway to Patagonia, has been plagued by parasites, pollution, and disease. Scottish salmon farms lost nearly 10 percent of their fish in 2012 to amoebic gill disease; in Chile infectious anemia has killed an estimated two billion dollars' worth of salmon since 2007. A disease outbreak in 2011 virtually wiped out the shrimp industry in Mozambique.

The problem isn't the ancient art of aquaculture per se; it's the rapid intensification of it. Chinese farmers started raising carp in their rice fields at least 2,500 years ago. But with that country's aquacultural output now at 42 million tons a year, fish pens line many rivers, lakes, and seashores. Farmers stock their ponds with fast-growing breeds of carp and tilapia and use concentrated fish feed to maximize their growth.

"I was very influenced by the green revolution in grains and rice," says Li Sifa, a fish geneticist at Shanghai Ocean University. Li is known as the "father of tilapia" for developing a fast-growing breed that's become the backbone of China's tilapia industry, which produces 1.5 million tons a year, much of it for export. "Good seeds are very important," Li says. "One good variety can raise a strong industry that can feed more people. That is my duty. To make better fish, more fish, so farmers can get rich and people can have more food."

How to do that without spreading disease and pollution? For tilapia farmer Bill Martin, the solution is simple: raise fish in tanks on land, not in pens in a lake or the sea. "Net pens are a total goat rodeo," says Martin, sitting in an office adorned with hunting trophies. "You've got sea lice, disease, escapement, and death. You compare that with a 100 percent controlled environment, possibly as close to zero impact on the oceans as we can get. If we don't leave the oceans alone, Mother Nature is going to kick our butts big-time."

Martin's fish factory, however, doesn't leave the land and air alone, and running it isn't cheap. To keep his fish alive, he needs a water-treatment system big enough for a small town; the electricity to power it comes from coal. Martin recirculates about 85 percent of the water in his tanks, and the rest—high in ammonia and fish waste—goes to the local sewage plant, while the voluminous solid waste heads to the landfill. To replace the lost water, he pumps half a million gallons a day from an underground aquifer. Martin's goals are to recirculate 99 percent of the water and to produce his own low-carbon electricity by capturing methane from the waste.

But those goals are still a few years away. And though Martin is convinced that recirculating systems are the future, so far only a few other companies are producing fish—including salmon, cobia, and trout—in tanks on land.

SOURCE: FAOSTAT

EIGHT MILES OFF THE COAST of Panama, Brian O'Hanlon is going in the exact opposite direction. On a calm day in May the 34-year-old president of Open Blue and I are lying at the bottom of a massive, diamond-shaped fish cage, 60 feet beneath the cobalt blue surface of the Caribbean, watching 40,000 cobia do a slow, hypnotic pirouette above us. The bubbles from our regulators rise up to meet them; one pauses to stare into my mask. Unlike Martin's tilapia or even the salmon in a commercial pen, these eight-pound youngsters have plenty of room.

O'Hanlon, a third-generation fishmonger from Long Island, grew up with New York City's famed Fulton Fish Market as his playground. In the early 1990s the collapse of the North Atlantic cod fishery and the import tariffs imposed on Norwegian salmon bankrupted the family business. His father and uncles kept saying that the industry's future was farmed fish. So as a teenager, O'Hanlon started raising red snapper in a giant tank in his parents' basement.

Now, off Panama, he operates the largest offshore fish farm in the world. He has some 200 employees, a big hatchery onshore, and a fleet of bright orange vessels to service a dozen of the giant cages, which can hold more than a million cobia. A popular sport fish, cobia has been caught commercially only in small quantities—in the wild the fish are too solitary—but its explosive growth rate makes it popular with farmers. Like salmon, it's full of healthy omega-3 fatty acids, and it produces a mild, buttery, white fillet that O'Hanlon claims is the perfect canvas for picky chefs. Last year he shipped 800 tons of cobia to high-end restaurants around the U.S. Next year he hopes to double that amount—and finally turn a profit.

Maintenance and operating costs are high in offshore waters. Although most salmon operations are tucked in protected coves near shore, the waves over O'Hanlon's cages can hit 20 feet or more. But all that rushing water is the point: He's using dilution to avoid pollution and disease. Not only are his cages stocked at a fraction of the density of the typical salmon farm, but also, sitting in deep water, they're constantly being flushed by the current and the waves. So far O'Hanlon hasn't had to treat the cobia with antibiotics, and researchers from the University of Miami have not detected any trace of fish waste outside his pens. They suspect the diluted waste is being scavenged by undernourished plankton, since the offshore waters are nutrient poor.

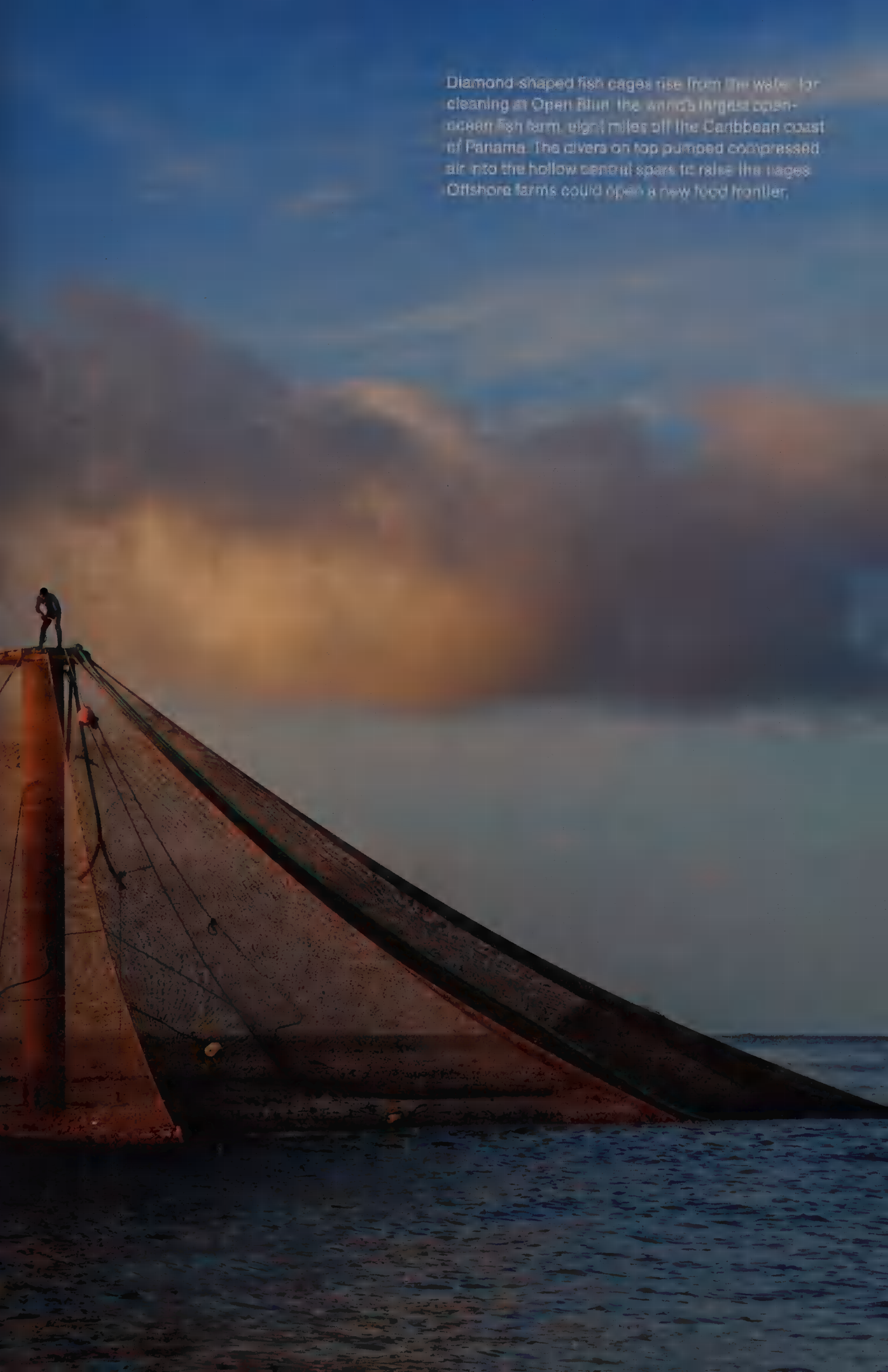
O'Hanlon is in Panama because he couldn't get a permit to build in the U.S. Public concerns over pollution and fierce opposition from commercial fishermen have made coastal states leery of any fish farms. But O'Hanlon is convinced he's pioneering the next big thing in aquaculture.

"This is the future," he says, once we've said goodbye to the cobia and are back aboard his orange skiff. "This is what the industry is going to have to do in order to keep growing, especially in the tropics." Recirculating systems like Martin's, he says, will never produce enough biomass. "There is no way they can scale up to meet the market demand. And to make one profitable, it's like a cattle feedlot, where you cram so many fish in you're just trying to keep them alive. You're not providing the best environment possible for them."

WHETHER YOU'RE RAISING fish in an offshore cage or in a filtered tank on land, you still have to feed them. They have one big advantage over land animals: You have to feed them a lot less. Fish need fewer calories, because they're cold-blooded and because, living in a buoyant environment, they don't fight gravity as much. It takes roughly a pound of feed to produce a pound of farmed fish; it takes almost two pounds of feed to produce a pound of chicken, about three for a pound of pork, and about seven for a pound of beef. As a source of animal protein that can meet the needs of nine billion people with the least demand on Earth's resources, aquaculture—particularly for omnivores like tilapia, carp, and catfish—looks like a good bet.

But some of the farmed fish that affluent consumers love to eat have a disadvantage as well: They're voracious carnivores. The rapid growth rate that makes

(Continued on page 110)



Diamond-shaped fish cages rise from the water for cleaning at Open Blue, the world's largest open-ocean fish farm, eight miles off the Caribbean coast of Panama. The divers on top pumped compressed air into the hollow cement spars to raise the cages. Offshore farms could open a new food frontier.

A diver nets a ten-pound cobia for sampling before harvest in one of Open Blue's dozen offshore pens. Able to hold hundreds of thousands of fish, but less densely stocked and better flushed than nearshore salmon pens, they produce little pollution. Cobia contain as much healthy fish oil as salmon do.

At dawn on China's Fujian coast, seaweed farmers head out to tend their aquatic fields. Such farms help China grow 12 million tons of food a year with no soil or fresh water and no fertilizer except runoff from the land. Oceans cover 71 percent of Earth yet provide less than 2 percent of our food—for now.

GEORGE STEINMETZ

Salmon farms gave the industry a black eye. But these days even salmon farms are producing 10 to 15 times the fish they did in the 1980s and 1990s with a fraction of the pollution.

cobia a good farm animal is fueled in the wild by a diet of smaller fish or crustaceans, which provide the perfect blend of nutrients—including the omega-3 fatty acids that cardiologists love. Cobia farmers such as O'Hanlon feed their fish pellets containing up to 25 percent fish meal and 5 percent fish oil, with the remainder mostly grain-based nutrients. The meal and oil come from forage fish like sardines and anchovies, which school in huge shoals off the Pacific coast of South America. These forage fisheries are among the largest in the world but are prone to spectacular collapses.

Aquaculture's share of the forage-fish catch has nearly doubled since 2000. It now gobbles up nearly 70 percent of the global fish meal supply and almost 90 percent of the world's fish oil. So hot is the market that many countries are sending ships to Antarctica to harvest more than 200,000 tons a year of tiny krill—a major food source for penguins, seals, and whales. Though much of the krill ends up in pharmaceuticals and other products, to critics of aquaculture the idea of vacuuming up the bottom of the food chain in order to churn out slabs of relatively cheap protein sounds like ecological insanity.

In their defense, fish farmers have been getting more efficient, farming omnivorous fish like tilapia and using feeds that contain soybeans and other grains; salmon feed these days is typically no more than 10 percent fish meal. The amount of forage fish used per pound of output has fallen by roughly 80 percent from what it was 15 years ago. It could fall a lot further, says Rick Barrows, who has been developing fish feeds at his U.S. Department of Agriculture lab in Bozeman, Montana, for the past three decades. "Fish don't require fish meal," says Barrows. "They require nutrients. We've been feeding mostly vegetarian diets to rainbow trout for 12 years now. Aquaculture could get out of fish meal today if it wanted to."

Replacing fish oil remains trickier, because it carries those prized omega-3 fatty acids. In the sea they're made by algae, then passed up the food chain, accumulating in higher concentrations along the way. Some feed companies are already extracting omega-3s directly from algae—the process used to make omega-3 for eggs and orange juice. That has the added benefit of reducing the DDT, PCBs, and dioxins that can also accumulate in farmed fish. An even quicker fix, Stanford's Rosamond Naylor says, would be to genetically modify canola oil to produce high levels of omega-3s.

FIGURING OUT what to feed farmed fish may ultimately be more important for the planet than the question of where to farm them. "The whole concept of moving into offshore waters and on land isn't because we've run out of space in the coastal zone," says Stephen Cross of the University of Victoria in British Columbia, who was an environmental consultant to the aquaculture industry for decades. Though pollution from coastal salmon farms gave the whole industry a black eye, he says, these days even salmon farms are producing 10 to 15 times the fish they did in the 1980s and 1990s with a fraction of the pollution. In a remote corner of Vancouver Island he's trying something new and even less damaging.

His inspiration comes from ancient China. More than a thousand years ago, during the Tang dynasty, Chinese farmers developed an intricate polyculture of carp, pigs, ducks, and vegetables on their small family farms, using the manure from ducks and pigs to fertilize the pond algae grazed by the carp. Carp were later added to flooded paddies, where the omnivorous fish gobbled up insect pests and weeds and fertilized the rice before becoming food themselves. Such carp-paddy polyculture became a mainstay of China's traditional fish-and-rice diet, sustaining millions of Chinese for centuries. It's still used on more than

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Contributing writer Joel K. Bourne, Jr., is working on a book about food. Brian Skerry photographed the bluefin tuna for our March issue.

seven million acres of paddies in the country.

In a fjord on the British Columbia coast, Cross has devised a polyculture of his own. He feeds only one species—a sleek, hardy native of the North Pacific known as sablefish or black cod. Slightly down current from their pens he has placed hanging baskets full of native cockles, oysters, and scallops as well as mussels that feed on the fine organic excretions of the fish. Next to the baskets he grows long lines of sugar kelp, used in soups and sushi and also to produce bioethanol; these aquatic plants filter the water even further, converting nearly all the remaining nitrates and phosphorus to plant tissue. On the seafloor, 80 feet below the fish pens, sea cucumbers—considered delicacies in China and Japan—vacuum up heavier organic waste that the other species miss. Minus the sablefish, Cross says, his system could be fitted onto existing fish farms to serve as a giant water filter that would produce extra food and profit.

"Nobody gets into farmed production without wanting to make a buck," he adds, over a plate of pan-seared sablefish and scallops the size of biscuits. "But you can't just go volume, volume, volume. We're going quality, diversity, and sustainability."

Perry Raso of Matunuck, Rhode Island, farms a monoculture, not a polyculture, but he doesn't feed his aquatic animals anything at all—and he's got 12 million of them. Raso is an oyster farmer, one of the new generation of shellfish growers who've been blessed by virtually everyone, from the Monterey Bay Aquarium Seafood Watch program to the new Aquaculture Stewardship Council, which recently published its first standards for shellfish. A key to sustainability, these groups say, is learning to eat farther down the food chain. Shellfish are just one step up from the bottom. And besides producing a healthy product low in fat and high in omega-3s, shellfish farms clean the water of excess nutrients.

Raso, with his powerful build, five-o'clock shadow, and fisherman's hoodie, looks more like the collegiate wrestler he once was than the greenest guy in the aquaculture business. He started his farm his senior year and was soon selling his oysters at farmers markets. "I'd get there, look around, and say, What am I doing around all these crunchy people?" Raso says. "But then I started making more money, started eating local foods, and you know what? That stuff was good." Raso now serves 800 people a day in the summer at the Matunuck Oyster Bar. Meanwhile the University of Rhode Island has sent him on teaching trips to Africa, where aquaculture is exploding—and where people desperately need affordable, healthy protein.

A few hundred miles north, in the clear, frigid waters off Casco Bay, two Maine watermen, Paul Dobbins and Tollef Olson, have stepped down the food chain even farther. After watching one commercial-fishery closure after another devastate Maine's coastal communities, they launched the first commercial kelp farm in the U.S., in 2009. They started with 3,000 linear feet of kelp line and last year farmed 30,000, harvesting three species that can grow up to five inches a day, even in winter. Their company, Ocean Approved, sells kelp as fresh-frozen, highly nutritious salad greens, slaw, and pasta to restaurants, schools, and hospitals along the Maine coast. Delegations from China, Japan, and South Korea have visited the farm—the seaweed industry is a five-billion-dollar business in East Asia.

Let us all eat kelp? "We call kelp the virtuous vegetable," says Dobbins, "because we are able to create a nutritious food product with no arable land, no fresh water, no fertilizer, and no pesticides. And we're helping clean the ocean while doing it. We think the ocean would approve." □

The Future of Food

ON THE WEB

Join the conversation at *natgeofood.com* and get daily food news, videos, informed blogs, interactive graphics, bonus photos, and food facts of the day.

The magazine thanks The Rockefeller Foundation and members of the National Geographic Society for their generous support of this series of articles.

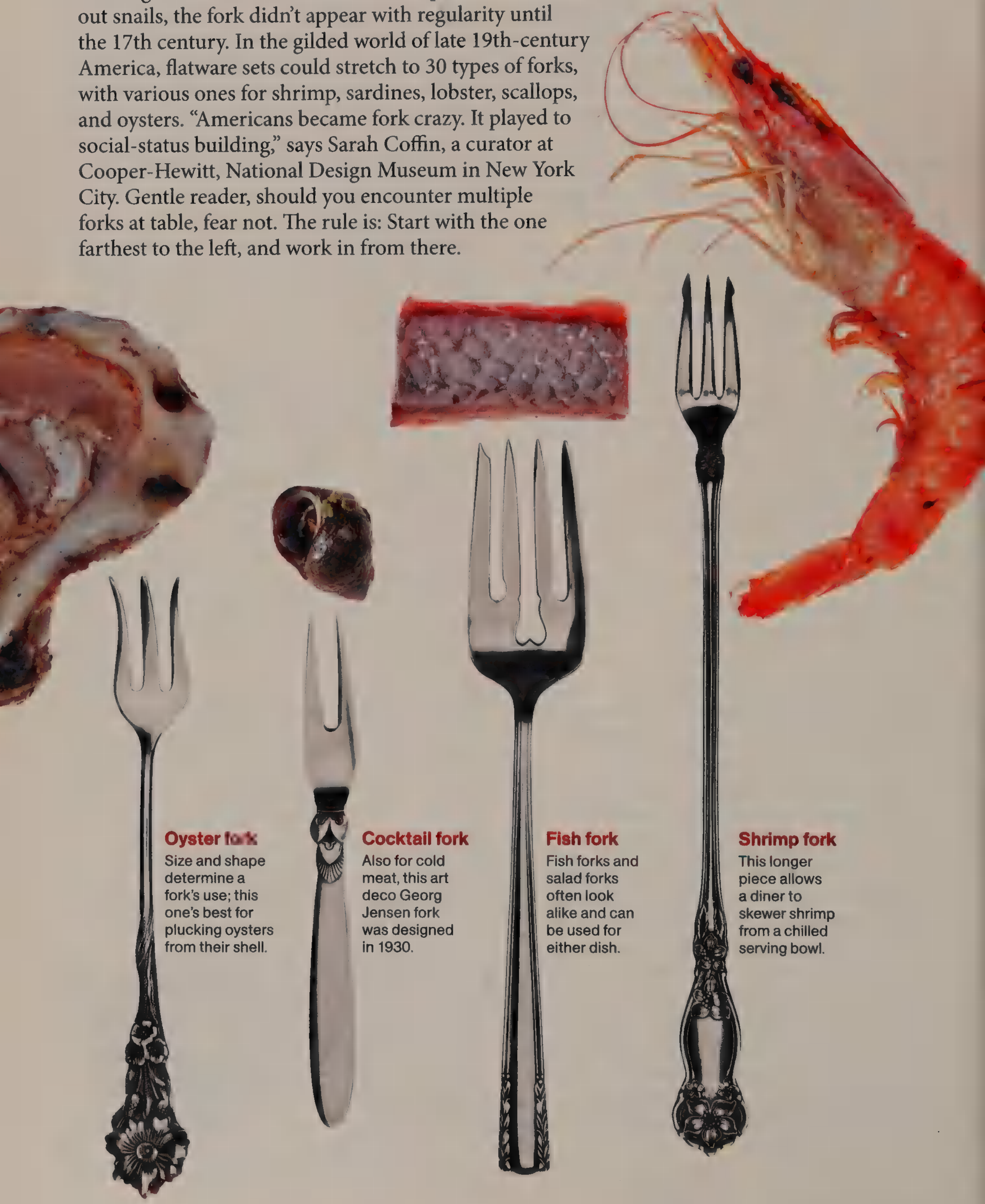
COMING IN JULY

Rich companies are buying up agricultural land in Africa.

Can Africa's
fertile farmland
feed the world?

Stick a Fork in It

Although ancient Romans used metal spikes to winkle out snails, the fork didn't appear with regularity until the 17th century. In the gilded world of late 19th-century America, flatware sets could stretch to 30 types of forks, with various ones for shrimp, sardines, lobster, scallops, and oysters. "Americans became fork crazy. It played to social-status building," says Sarah Coffin, a curator at Cooper-Hewitt, National Design Museum in New York City. Gentle reader, should you encounter multiple forks at table, fear not. The rule is: Start with the one farthest to the left, and work in from there.

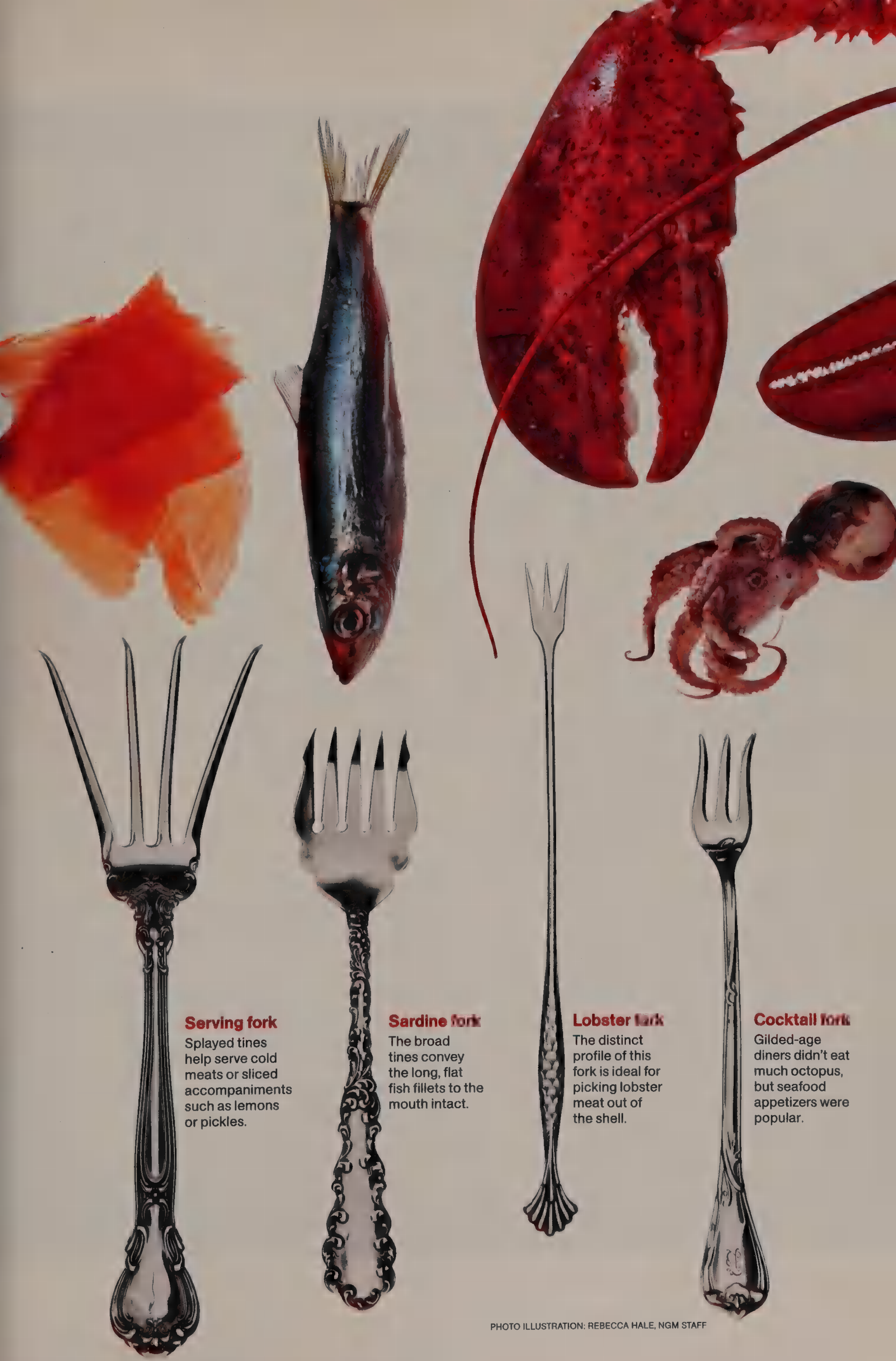


Oyster fork
Size and shape determine a fork's use; this one's best for plucking oysters from their shell.

Cocktail fork
Also for cold meat, this art deco Georg Jensen fork was designed in 1930.

Fish fork
Fish forks and salad forks often look alike and can be used for either dish.

Shrimp fork
This longer piece allows a diner to skewer shrimp from a chilled serving bowl.



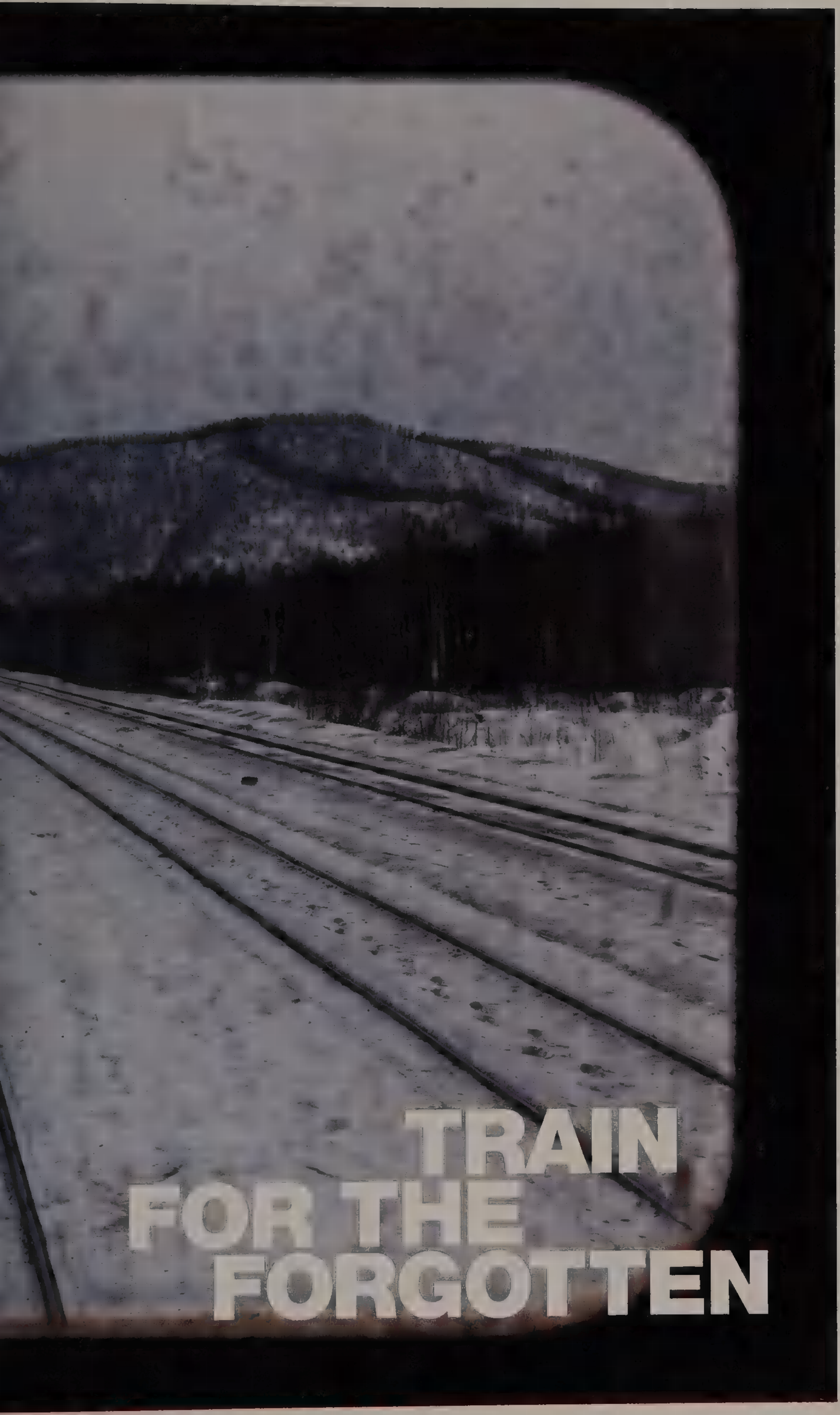
Serving fork
Splayed tines help serve cold meats or sliced accompaniments such as lemons or pickles.

Sardine fork
The broad tines convey the long, flat fish fillets to the mouth intact.

Lobster fork
The distinct profile of this fork is ideal for picking lobster meat out of the shell.

Cocktail fork
Gilded-age diners didn't eat much octopus, but seafood appetizers were popular.

PHOTO ILLUSTRATION: REBECCA HALE, NGM STAFF



TRAIN FOR THE FORGOTTEN

A view from the back of the *Matvei Mudrov* medical train as it stops to offer care in the tiny Siberian village of Kenay

Medical staff set up an EEG for Nadezhda Gaskevitch, 38, who slipped on ice a decade ago and still needs regular brain scans.

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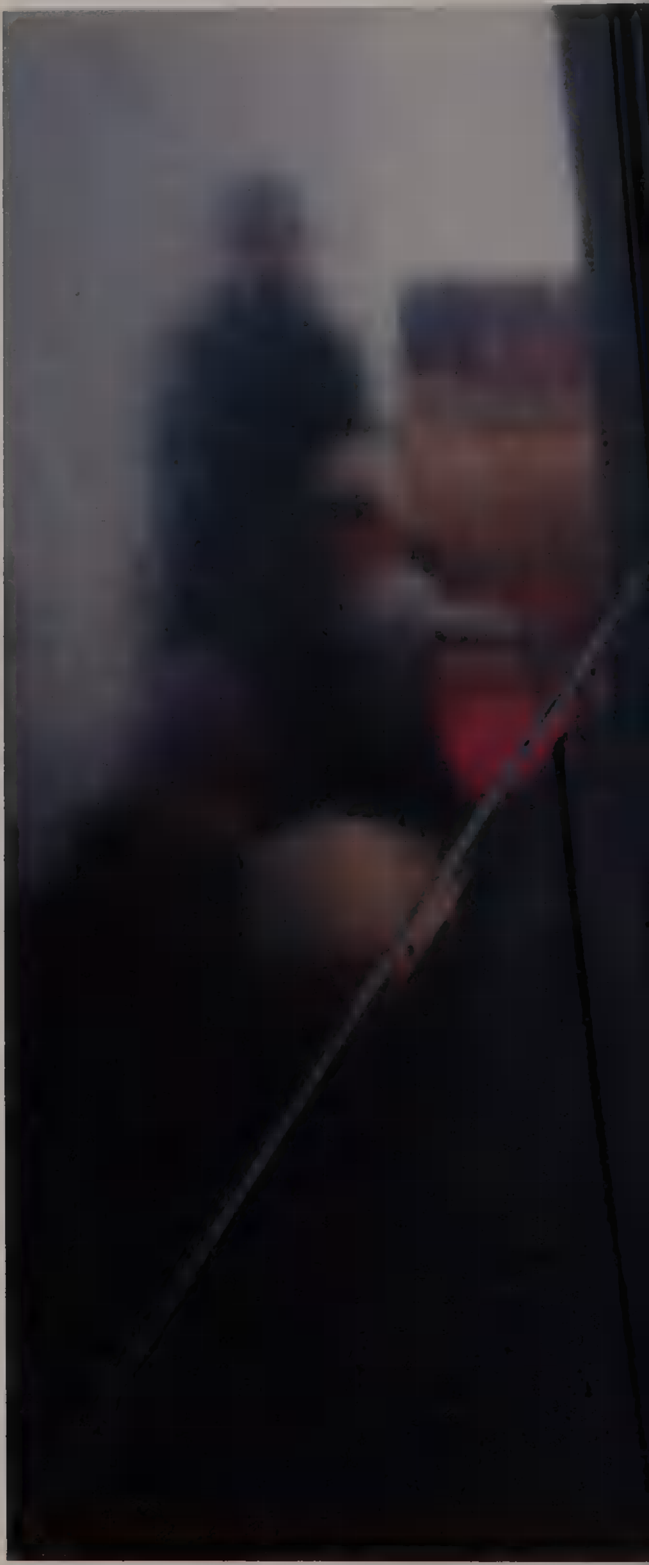
BY JOSHUA YAFFA
PHOTOGRAPHS BY WILLIAM DANIELS

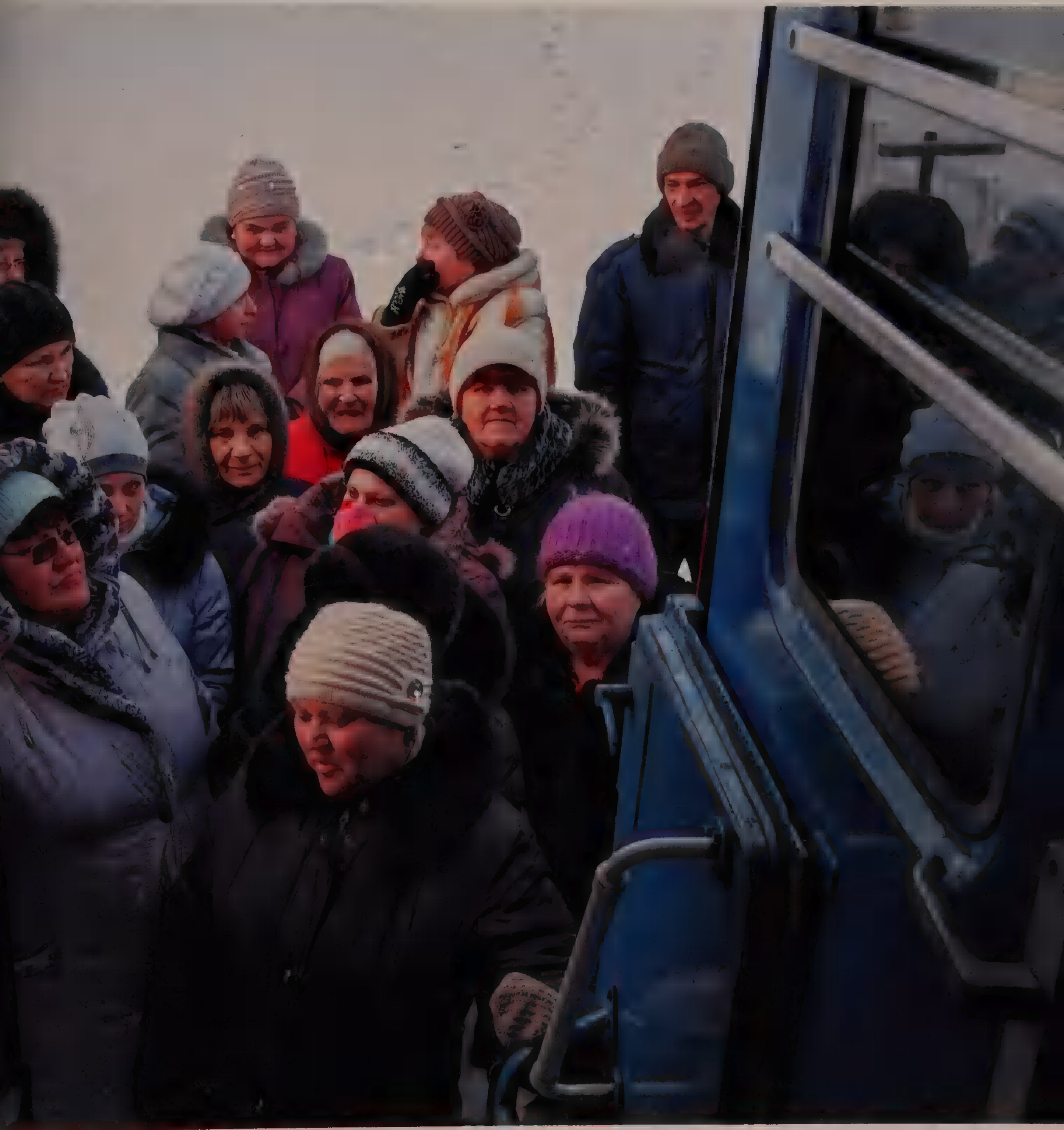
THE AILING AND THE INJURED AWAIT the train at every stop. In Khani, a village of 742 people wedged between the snowy peaks of the Stanovoy Mountains, patients emerge from concrete buildings and gather along the tracks. They all seek medical treatment. One man fell down a staircase while drunk and broke both of his ankles. A teacher at the only school in town wants a checkup for her 14-year-old daughter, who came down with appendicitis a month earlier and was, quite luckily, evacuated on a cargo train. She had her appendix removed in Chara, three anguished hours away.

These and other patients are waiting now to board the *Matvei Mudrov* medical train. This is Khani's main lifeline—a mobile medical clinic with basic equipment, exam rooms, and 12 to 15 doctors. Run by the Russian state railways agency and named for a 19th-century physician who helped establish clinical practice in Russia, the *Matvei Mudrov* runs from village to village, stopping for a day to see patients, then continuing along the thousands of miles of track that stretch across the Russian Far East.

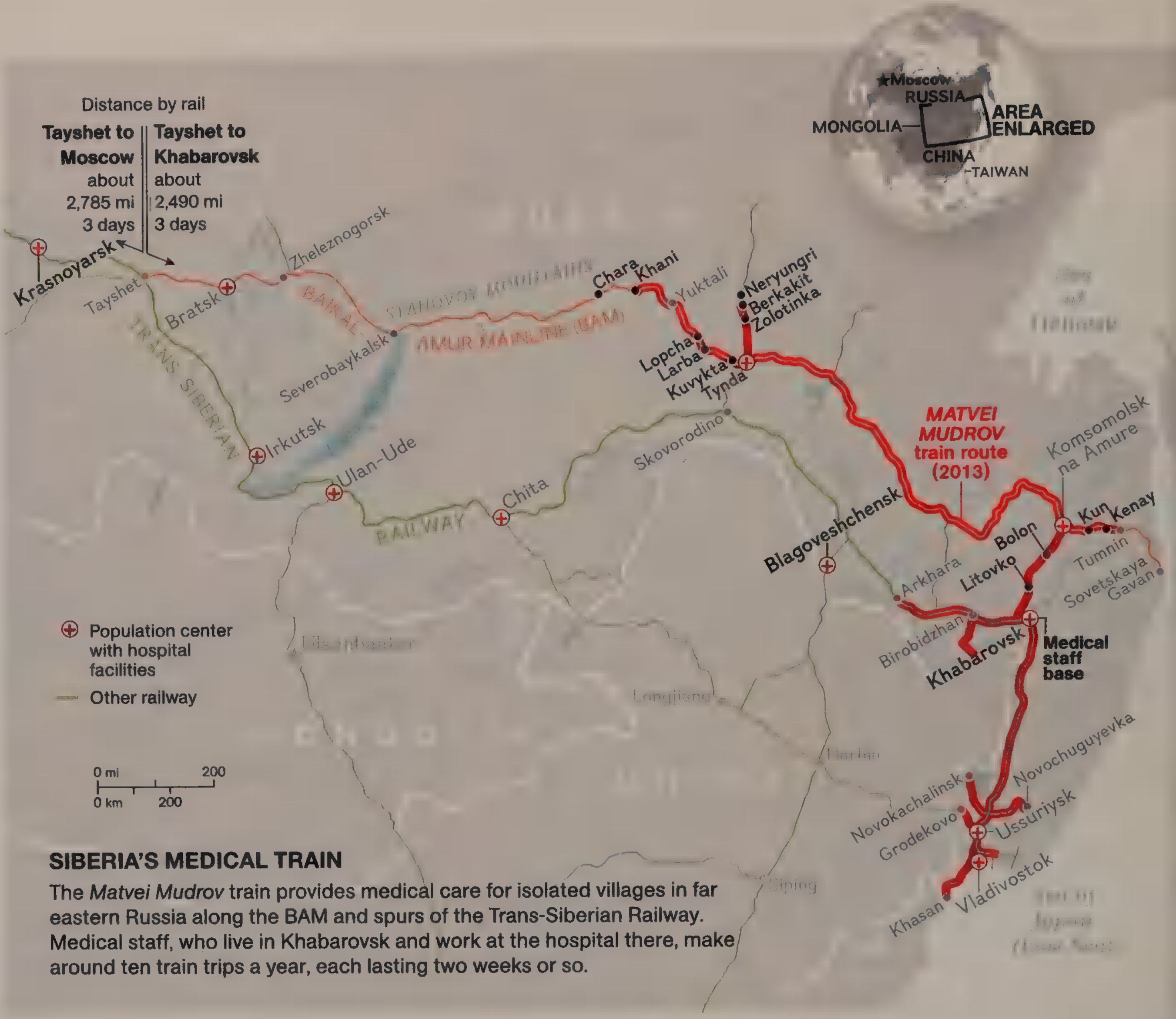
Khani is in many ways typical of communities along the rail line: A yard of rough gravel and stone ringed by five-story, prefabricated apartment blocks forms the center of town, which seems largely deserted. The people have no surgeon of their own, no specialists—just a small clinic with Soviet-era equipment and an all-purpose doctor who was educated as a dentist. For many, the *Matvei Mudrov* is the only expert attention they get.

In the afternoon I take a walk with Khani's one police officer, Nikolay Kolesnik, who is 29 and has a smooth, boyish complexion and hair so blond it seems almost translucent. He only arrived the previous winter; for the six years before that, the village had no police officer at all. His one pair of boots tore open after a month,





Villagers in Litovko wait in 5°F weather until the medical train's doors open at 9 a.m. The state covers the cost of the care offered on the train.


Distance by rail
Tayshet to Moscow about 2,785 mi 3 days
Tayshet to Khabarovsk about 2,490 mi 3 days
Moscow
RUSSIA
MONGOLIA
CHINA
TAIWAN
AREA ENLARGED
Krasnoyarsk
Tayshet
Zheleznogorsk
Bratsk
BAIKAL
STANOVOY MOUNTAINS
AMUR MAINLINE (BAM)
TRANS-SIBERIAN
Severobaykalsk
Irkutsk
Ulan-Ude
Chita
RAILWAY
Chara
Khani
Yuktali
Lopcha
Larba
Kuvykta
Tynda
Neryungri
Berkakit
Zolotinka
Skovorodino
Blagoveshchensk
MATVEI MUDROV train route (2013)
Komsomolsk na Amure
Kun
Kenay
Bolon
Litovko
Tumnin
Sovetskaya Gavan
Arkhara
Birobidzhan
Khabarovsk
Medical staff base
Novochuguyevka
Novokachalinsk
Grodekovo
Ussuriysk
Vladivostok
Khasan
Ulaanbaatar
Longjiang
Harbin
Siping
Population center with hospital facilities
Other railway
0 mi 200
0 km 200

SIBERIA'S MEDICAL TRAIN

The *Matvei Mudrov* train provides medical care for isolated villages in far eastern Russia along the BAM and spurs of the Trans-Siberian Railway. Medical staff, who live in Khabarovsk and work at the hospital there, make around ten train trips a year, each lasting two weeks or so.

and because there are no clothing stores in the village or anywhere nearby, he had to take a train 20 hours back to the regional capital to buy new ones.

These are minor annoyances compared with the impact Khani's remote location has on Kolesnik's job. The village has no jail, which means he can't make arrests for serious crimes. He can't even enforce drunk-driving laws: He doesn't have a Breathalyzer, let alone a medical technician to do a legally admissible analysis. There is no morgue or even a doctor qualified to sign a death certificate, which means dead bodies wait in an old brick warehouse by the rail tracks for pathologists to come by train and get them.

Kolesnik nevertheless insists that he enjoys it here. Life is simpler, the people are nicer, and the job has a calm rhythm to it—he likes the locals, and judging by the friendly nods he gets as he walks around town, they like him.

Joshua Yaffa is a journalist who lives in Moscow. William Daniels is an award-winning photographer based in Paris.

His affection is not widely shared, however. Three days earlier, his girlfriend left town, taking their seven-year-old daughter along with her. "I'm never coming back to this place for the rest of my life," she told him.

THE *MATVEI MUDROV* serves dozens of villages like Khani along the Baikal-Amur Mainline (BAM), so called because it stretches from Lake Baikal to the Amur River. The BAM runs for 2,672 miles, parallel to the better known Trans-Siberian line but 400 miles or so to the north. Built in the late 1970s and early '80s, it was the last great Soviet construction project—meant, like those before it, to showcase man's conquest of nature, made possible by feats of Soviet engineering and the will of the Soviet people. The grandeur and messianism of the project

LAUREN E. JAMES AND ALEXANDER STEGMAIER, NGM STAFF. SOURCE: RUSSIAN RAILWAYS were as much the point as the railway itself.

Soviet leader Leonid Brezhnev gave much of the responsibility for building the BAM to the Komsomol, the Communist Party's youth wing, which imbued the project with a spirit of exuberance. Between 1974 and 1984, 500,000 people were involved in its construction. They were drawn by the romance of sleeping in wooden barracks in the forest and also by salaries up to three times the Soviet average. Many workers were even promised that after three years on the BAM, they would get a voucher for a new car, an almost mythical luxury at the time.

Little did these pioneers know that the end of this heroic experiment was just a few years away. In 1991, when the Soviet Union disappeared, so too did the resources and enthusiasm to promote and maintain the BAM. By the mid-1990s the region had fallen prey to alcoholism, poverty, and isolation. Many people left. Those who stayed have grown old in an unforgiving environment. Winter temperatures often reach 60° below zero F. In a region with few roads suitable for automobiles, the main route in or out is the railroad. The villages along the BAM survive like an archipelago of small, secluded islands carved out of the wilderness. Not surprisingly, access to dependable health care is limited.

The *Matvei Mudrov* train is not equipped for even lightly invasive procedures, let alone surgery, though its doctors can offer a diagnosis and recommend a course of treatment. But the medical train is one of the few points of contact those along the BAM have with the rest of the country. (Locals refer to other parts of Russia as "on land.") The train offers them a sign that the rest of Russia knows that they exist, remembers them, and on some level, cares if they live or die.

THE TOWN OF BERKAKIT is made up of a few streets and rows of prefabricated apartment blocks, their paint long faded and foundations ever threatening to sink into the damp permafrost. It was built in the mid-1970s as a transport hub for the BAM and was once home to as many as 9,000 people. Now less than half remain. By around nine in the morning, when the doctors on the *Matvei Mudrov* begin seeing patients, a line has formed along the tracks.

Among those patiently waiting is Mikhail Zdanovich, a 61-year-old man with a wide face sheathed in heavy, pink skin. His right arm with its dislocated shoulder is in a fabric sling: He is waiting his turn for surgery in Khabarovsk, about a thousand miles away. That is months off. He wants to ask the doctors if he should work in the meantime.

Zdanovich tells me he was sent to the BAM in 1976, when he had just finished Soviet military service. At the time Berkakit was a tiny settlement of a hundred or so young people living in hastily built dormitories. "There was one road—well, they called it a road—but it was no road at all," he says. Life was hard but also simple and charming. The work in freezing weather was tough but made bearable by parties at night with cognac and Soviet-made champagne. At school, children lunched on bread smothered with black caviar; the handful of shops in town carried almost unheard-of treats, like Japanese clothes and Hungarian jam, shipped in at great expense to keep the workers happy. After a year Zdanovich met a woman who worked at the town bakery; she became his wife.

THE TRAIN OFFERS A SIGN THAT THE REST OF RUSSIA KNOWS THEY EXIST, REMEMBERS THEM, AND ON SOME LEVEL, CARES IF THEY LIVE OR DIE.

Now he is employed as a repairman at the local depot. Three years ago he threw out his shoulder while pushing a train car into place; his bosses at the state railways agency urged him to go home and rest but not to file a report. He has been living with his painful, largely immovable shoulder ever since, somehow not so bothered by it, or at least not enough to get himself on a

The *Matvei Mudrov* pulls into Kun, which means "valley of snow." There's no running water in the village; only a few families remain.

Liza Bazhanova, eight, waits for test results from a general checkup. Even this first grader complains about the lack of decent health care in her village.

train for the long journey to a proper hospital.

Just about the only employment along the BAM is with the railways agency, which maintains the tracks for those living on the BAM, who have no other means of getting around. It's a closed system, and in this way and others, life feels much as it did in the waning years of the Soviet Union.

Moscow's furious, oil-fueled construction boom means nothing here. No new shopping centers or apartment towers or movie theaters have appeared over the past 20 years. But while the benefits promised by free-market capitalism have not arrived, many of the privileges offered by the Soviet system, like subsidized vacations to the Black Sea, have disappeared. As Zdanovich says, using a common Russian expression, "Now we're not needed for horseradish by anybody."

BABUSHKAS COME IN WANTING ULTRASOUNDS OF EVERYTHING BECAUSE THEY HEARD OF THE PROCEDURE ON A TV SHOW STARRING DR. AGAPKIN.

As soon as Zdanovich walks into the office of Yelena Miroshnichenko, the train's general surgeon, she cries out, "Oh Mikhail Pavlovich, I knew I recognized that voice!" He takes his limp arm out of its sling and has her feel his shoulder. His bosses were supposed to reassign him to technical work, but they still give him tough physical jobs at the rail yard. "I can't work, but that's no interest to them," he says. He asks Miroshnichenko if he needs to pay a bit extra to move up in line for surgery. She says probably not but writes a letter saying he is unfit for labor in the meantime. He walks out happy and returns a few minutes later with freshly baked cabbage pies and a glass jar of goat milk. "Take them," he insists. After years of treating patients in the small villages of the BAM, Miroshnichenko says, "You don't just know people, you know the dogs."

THE NEXT DAY the train stops to see patients in Zolotinka, a village of half-empty apartment blocks built on a hill. Since the ticket office at the train station closed in 2012, Zolotinka has become even more cut off. Now residents wanting to travel on the BAM have to drive 45 miles on an unpaved road to Neryungri to buy tickets. It's complicated to go just about anywhere, so people tend not to. As a crowd gathers and people start to vent their frustrations about traveling, one man leans over to me and says, "If the Soviet Union had been able to hang on another two years, we'd have asphalt all the way to Neryungri!"

A few cars down, near the train's laboratory, I come across a young girl with a pink jacket and a long blond braid, pacing the corridor, waiting for her mother. Her name is Anya, and she is in the seventh grade—one of two children in her class. "It's just me and Andrei, and he's a jerk, I'll tell you that right away," she says. Anya tells me she likes big cities, though the largest she's ever been to is Blagoveshchensk, a regional hub of 200,000 people on the border with China. "I've already told my mom, as soon as I finish school, I'm moving to Moscow," she says. As she imagines it, the capital is a city of "big, open squares, with lots of places to take photos, and towers with clocks on them." Maybe, though, she wants to live in London, where "they have a big tower with a clock too."

Later that afternoon I run into Anya and a few of her friends at the playground that is their one source of entertainment in Zolotinka, and I walk with them up the hill toward an abandoned white-brick barracks. They climb up the rotted staircases and jump over shards of glass, playing a shrieking, whirling game of hide-and-seek. After a few minutes a woman in her 60s runs up, scolding the children and yelling at me, or at no one in particular, perhaps just wanting to amuse herself with the scandal she has created. The kids go home and I walk back to the train.

After a week on the *Matvei Mudrov*, life settles into a rhythm that is soothing in its repetition: the green pines of the surrounding forest, the

After receiving a rare house call from the *Matvei Mudrov*'s general surgeon, Albert Popov, 45, a paraplegic, performs his first rehabilitation therapy in a year.

guttural rumble of the train's engine, the hypnotic *clop clop clop* of the tracks below. The cook, a 27-year-old jokester named Vitya, serves three meals a day; I find myself waking up hungry for his doughy, fried blini with jam, which the doctors eat standing up behind the laminate counters in the dining car. They amuse one another with tales of patients, like the babushkas who come in wanting ultrasounds of everything because they heard of the procedure on a medical TV show starring Dr. Agapkin.

The train visits each village along the BAM roughly twice a year. Its main powers are diagnostic: It has a lab for blood and urine analysis, EKG and EEG monitors, an ultrasound, and an x-ray machine. Doctors write out courses of treatment and recommended drugs—but just as often, offer reassurance and basic instruction, like the admonition that instant coffee alone doesn't provide enough hydration to prevent kidney stones. I hear many patients praise the medical staff for their honesty and competency. Doctors along the BAM, I am told, often have long lines slowed by bureaucratic formalities or try to funnel people to their after-hours, cash-only practices.

Consultations happen mostly on the train, but every now and then the doctors make a house call. One day in Lopcha I get into an old jeep with

“If you have appendicitis, you can directly go to the cemetery,” says Bolon resident Vladimir Petrenko (at right). He lives a long, complicated train-and-bus trek from urgent care.

ADMLIS

Dr. Miroshnichenko to drive down the village's one muddy, potholed road. We arrive at an apartment block made of concrete slab that looks exactly like every other apartment block I have seen on the BAM. We climb a dark stairwell, stopping outside a door on the third floor. A woman named Vera Popova opens it. Popova, who is 67, came to the BAM in 1980 with her husband, a welder for the railways who died three years ago of a heart attack.

She leads us to the back bedroom, where we meet her 45-year-old son, Albert. Early one morning in 2007, Albert was walking along a crossbeam of an abandoned apartment building when he slipped on an invisible slick of ice. He fell six feet to the cold, wet earth. "I had the sensation like my whole body was in jelly," he tells me. He lay there until some friends came; they carried him by his hands and feet to wait for a train headed in the direction of a hospital around five hours away. He was paralyzed from the waist down. Doctors sent him home, and the state gave him a certificate pronouncing him a medical invalid. It wasn't so much "a diagnosis, but a sentence," he thought.

Now he passes his time watching documentaries and getting into fights about history, politics, and psychology in Internet chat rooms. His mom washes him and massages his back and legs. He is unable to use the toilet, so he lies on his back in diapers that his mother changes a few times a day.

Some hope came when an old friend told him about an advanced rehabilitation facility in Krasnoyarsk, a large city farther west in Siberia. Doctors there showed him exercises to rebuild strength and, one day, possibly regain the ability to walk. But the last time he was there he injured his knee. He hasn't gotten up from bed since. He could see a doctor in Tynda, five hours away by train, but for that he would have to ask friends to carry him to the station and then endure an uncomfortable ride propped up on a stiff bench, and he just doesn't have the energy for it anymore. That's why he and his mother asked the doctors from the train to come have a look.

They want to know if his knee has healed and whether he can resume a light rehab program at home. Miroshnichenko pokes around, lifting his leg and testing his reflexes. "You can stand, put weight on it—go ahead," she says. Albert's mom brightens at hearing that he can resume exercises. She clasps her hands together, then goes to embrace Miroshnichenko. "Good God, thank you, thank you," she says, shoving a paper bag with two smoked fish into her arms.

THE VILLAGES ALONG THE BAM were built by work brigades from various corners of the Soviet Union: the Ural Mountains, Georgia, St. Petersburg, elsewhere. The village of Larba was built by laborers from Soviet Turkmenistan. Only one is left: Abdikerim Mukhamedmazorovich, a lanky 49-year-old with a thin, silver mustache, who takes me to see the cemetery. "We have one illness here," Abdikerim says, clicking his index finger against his neck, the Russian symbol for drunkenness. "You see, Ast drank and drank. Tuyev, he also got burned by spirits. Sergei was drinking, got hit by a train. This one, he never cured his hangover. Liliya got all the way hammered. Netukhov drank and drank, and drowned in the river." Later Abdikerim alludes to how his wife has her own problems with alcohol. He then quickly changes the subject: He wants to show me the land above the river where Soviet generals once had their dachas.

The last stop on this *Mudrov* trip is Kuvykta. The morning is gray and rainy, and pools of water form on the dirt path in front of the train. By this point in the trip, more than three weeks after the train first left Khabarovsk, the doctors are tired, a little less quick to crack a joke. I stop by the room of Alexander Komarov, the train's neurologist. In the mid-1980s, before he became a doctor, Komarov came to Kuvykta as part of a Komsomol brigade sent to work on the BAM. "I haven't been back in 30 years," he tells me.

We decide to go for a walk around the village. Komarov was 22 years old when he first came here, a medical student just out of the Soviet Army. "They asked us, 'Don't you want to repay your debt to your motherland and go work on the BAM?'" Why not? he thought. "The whole country was building railway tracks, stations,

Two staffers celebrate the birthday of medical director Vera Scherbakova. In the background is a portrait of Matvei Mudrov, a pioneering 19th-century physician who is the train's namesake.

villages," and he wanted "to offer something of my own." Everyone lived in a temporary settlement on a patch of dry earth by the river. "There were hills all around, quiet, no people... the end of the Earth." There was a romanticism in the roughness of BAM life: He would wake up at 6 a.m., walk out of his tent to brush his teeth in the river, have breakfast with the other young BAM laborers, then spend the day doing construction work, cracking jokes, and tanning in the summer sun. At night the group would light a fire and play guitars.

Komarov can no longer remember where exactly the camp was located. A heating plant of red brick and metal sits rusted and unused. "It hurts that all this labor was in vain," he says. "We tried, really strived to achieve something, and it turns out that today our work isn't needed by anybody." We slog through the mud, following a path that takes us to the riverbank. Komarov picks up a handful of small stones, rubbing the wet earth in his fingers, trying to conjure up a memory of where he lived and worked and slept and sang so many years ago. It was around here, he says. Or maybe not. We stand for a few minutes, not saying much, looking at the slow current of the river and feeling our shoes squish into the mud, then turn around and walk back toward the train. □

ПКДЦ ТЕРАПЕ

The staff takes an after-hours break. They'll swig vodka, eat barbecue, and burn a straw effigy to mark the folk holiday before Russian Orthodox Lent.

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NG CONNECT

Every month this page features our staff picks of National Geographic Society products and events. For more go to *nglive.org*.

NATIONAL GEOGRAPHIC ON TV

Inside Combat Rescue

This month the National Geographic Channel takes viewers to the heart of the war in Afghanistan. When four Americans are killed at Bagram Airfield by Taliban rockets, our camera crews embed with elite Air Force units as they fly to rescue the wounded and go on the offensive, hunting down the insurgents responsible for the attack.

TRIP

SAFARIS National Geographic's expert-led safaris offer a range of ways to discover the world's wildlife, from walking with the Maasai in Tanzania to spotting tigers in India and leopards (left) in Botswana's private game reserves. Choose the safari that best suits your interests at *ngexpeditions.com/safari.*

EXHIBIT

COSMOS: A SPACETIME ODYSSEY An interactive companion to the National Geographic Channel series of the same name, this exhibit in Washington, D.C., explores the vastness of the universe in the spirit of Carl Sagan's 1980 hit. For more information visit *ngmuseum.org.*

INITIATIVE

CHANGE THE COURSE The Colorado River is drying. Help replenish it by pledging to shrink your water footprint at *changethecourse.us.*

LECTURE

CORAL, FIRE, AND ICE David Doubilet (right, in Antarctica) is an award-winning underwater photographer. Find out where you can hear him speak this year at *nglive.org/doubilet.*

Book of the Month

true!
HEADLINES

Weird but True! Ripped From the Headlines

Ever heard about Boston's Great Molasses Flood of 1919, in which 21 people drowned? How about the shark cyclops discovered off the coast of California? These and other surprising news stories from past and present are featured in this latest addition to the Weird but True series. On sale June 24 wherever books are sold ($12.99).

PHOTOS (FROM TOP): PETER SILVERMAN, NATIONAL GEOGRAPHIC TELEVISION; BEVERLY JOUBERT, NATIONAL GEOGRAPHIC CREATIVE; STEVE JONES

Shadow of the Past

Robert Clark has shot a lot of archaeology stories for the magazine, including several in Peru. But he calls this month's feature on the northern Wari people ("Untouched") "just amazing. By far the richest dig I've ever been on."

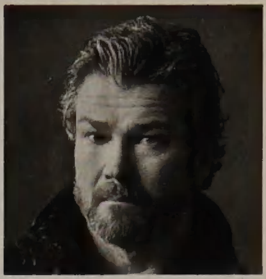
A 1,200-year-old tomb known as El Castillo de Huarmey—unlooted at a much plundered site—is yielding new insights into South America's first empire builders. Yet mysteries remain. One was in Clark's hotel.

"Behind the front desk was a Wari pot," he says. "The owner said he bought it from a tomb raider, like a lot of people around town had."

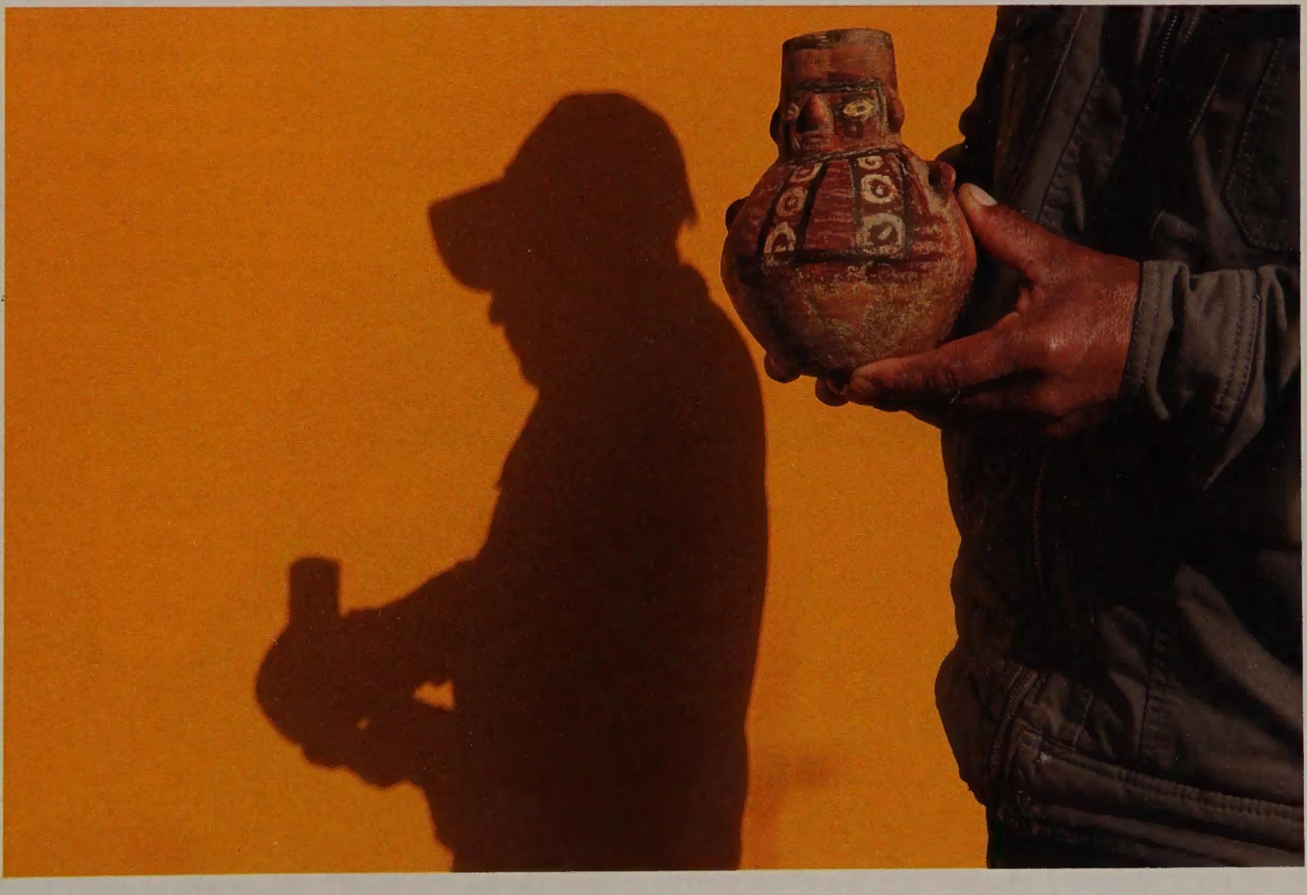
Over the next three weeks, as Clark photographed the dig site and objects being studied in a lab, he thought about the pot. "I wanted to show its beauty," he says, "and I wondered about its history. Where has it been? And who looted it? It was a shadowy figure, in my interpretation."

On his last day in town, minutes before leaving for Lima, he brought that image to life. Drawing on his past experience as a portrait photographer—"that's where I learned about shadow and lighting"—he took the shot below of a hotel employee holding the pot, silhouetted against a wall.

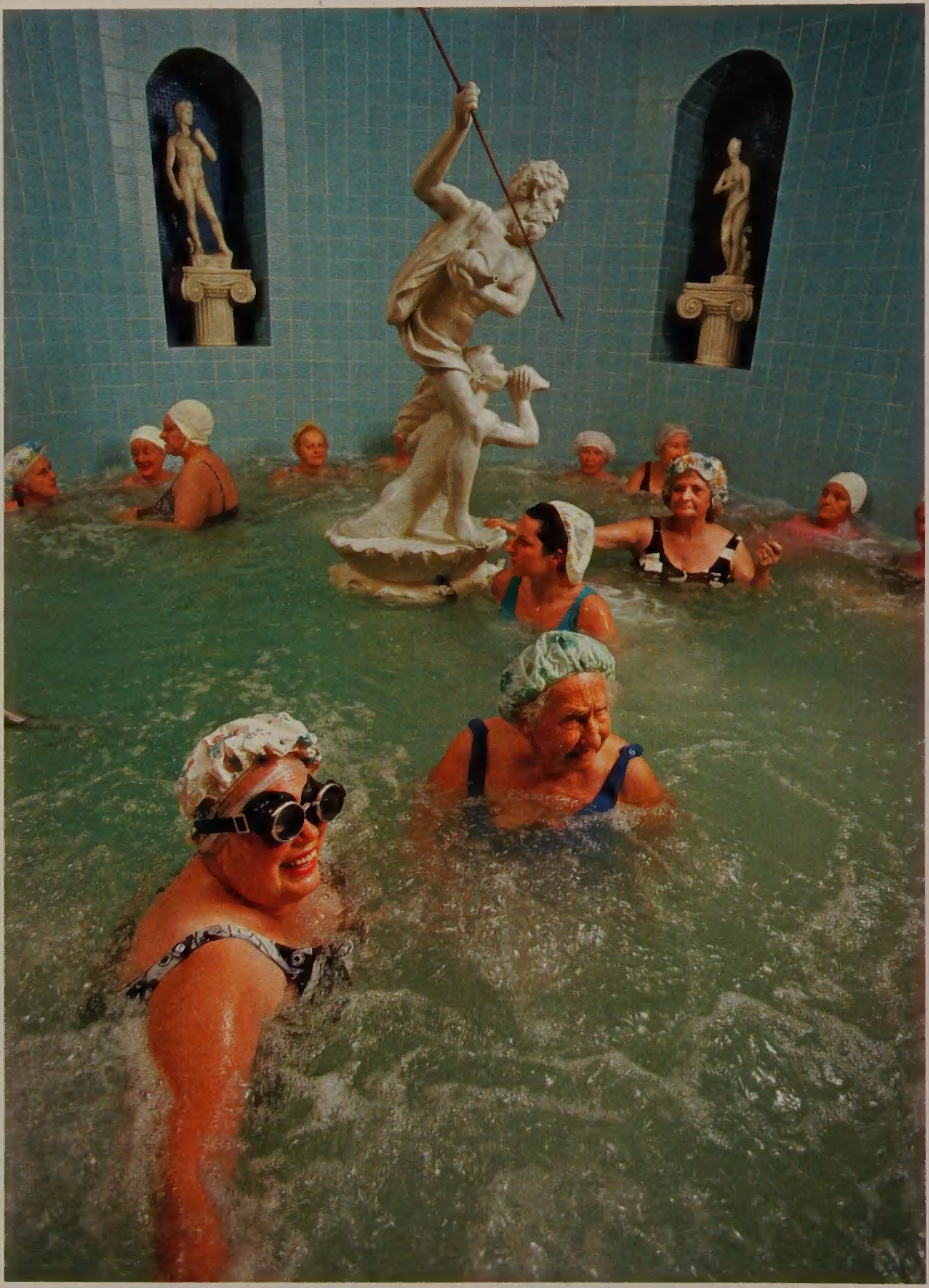
"It was the very last photo I made," Clark says, "and it happened really quickly. A lot of times you preplan and preplan. But sometimes a picture just comes together in the moment." *—Jeremy Berlin*



Listen to an interview with Robert Clark on our digital editions.



PHOTOS: ROBERT CLARK



Hot Club

Women once warmed to the 109°F whirlpool bath—and scantily clad statuary—on Mondays, Wednesdays, and Fridays at the European Health Spa in St. Petersburg, Florida. Men had access to the facility on Tuesdays, Thursdays, and Saturdays. No information is available about what happened on Sundays.

This photo was originally published in *National Geographic*'s November 1973 issue with an article called "Florida's Booming—and Beleaguered—Heartland." These days any beleaguered visitors to the site of the long-closed spa may seek a different sort of relaxation: It is now a liquor store.

—Margaret G. Zackowitz

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PHOTO: JONATHAN BLAIR, NATIONAL GEOGRAPHIC CREATIVE

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